How To Photograph This Month's Lunar Eclipse

ASTRONOMY

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- Soup Up Your Newtonian Telescope
- How Astronomers Lost Neptune

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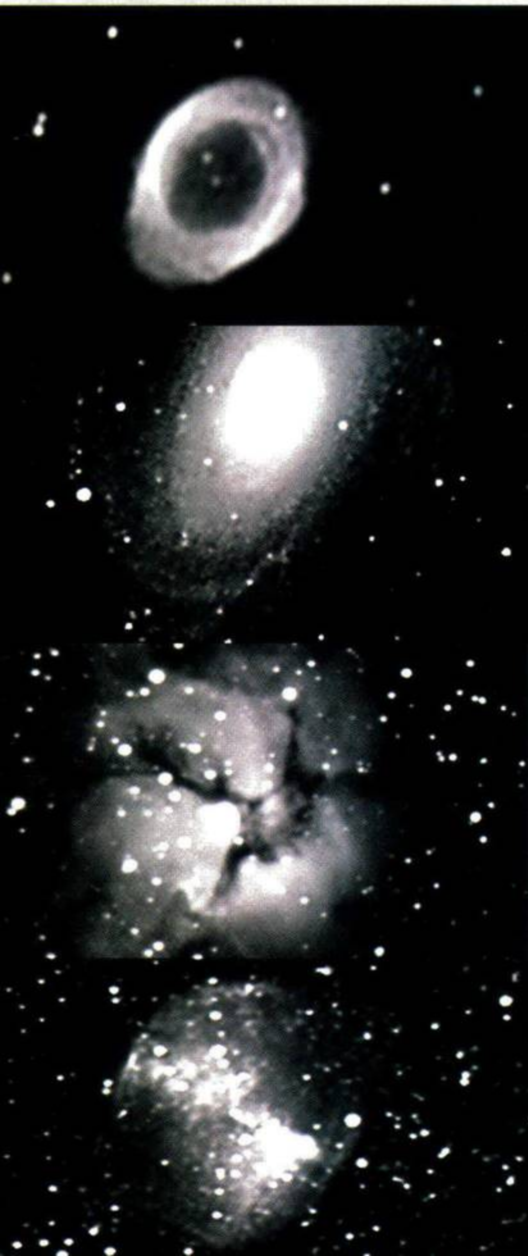
Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot; Dumbbell Nebula (M27), 12" LX200, John Hoot.



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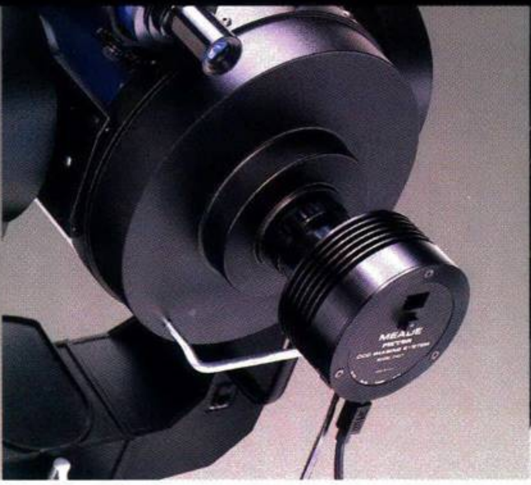
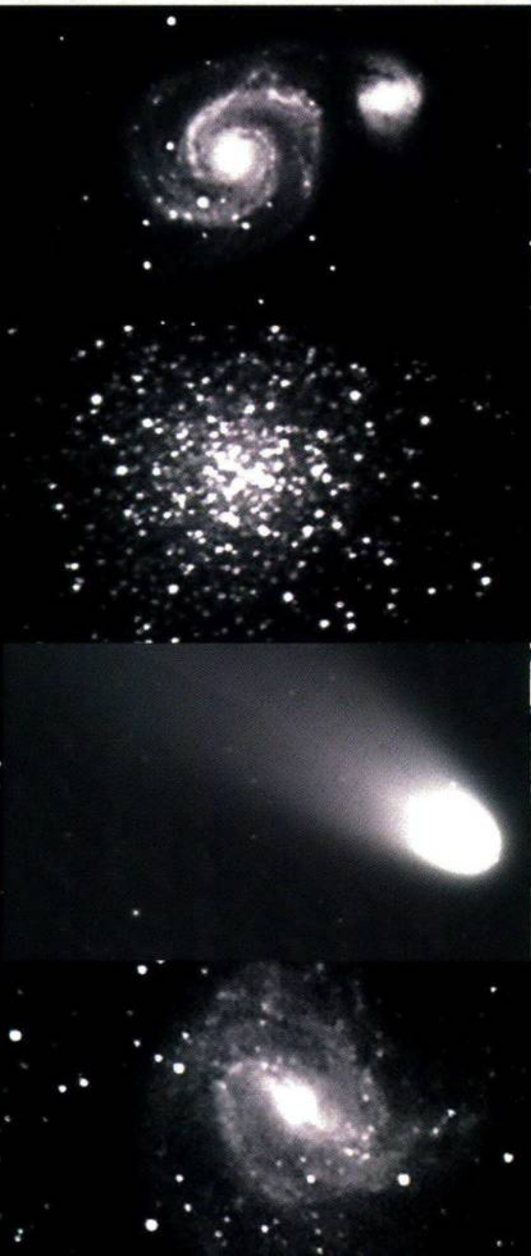


Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Comet Hyakutake, 8" LX200 with f/6.3 Focal Reducer, John Hoot; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



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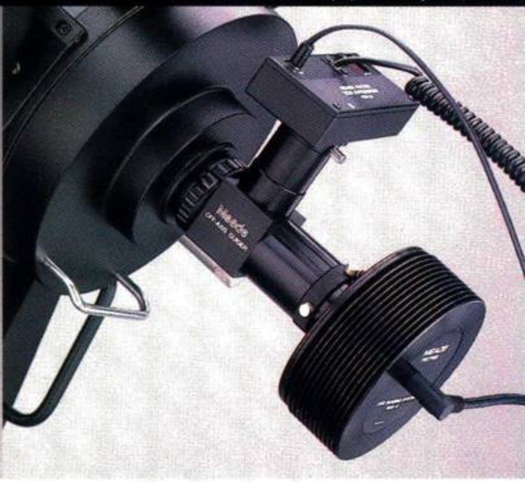
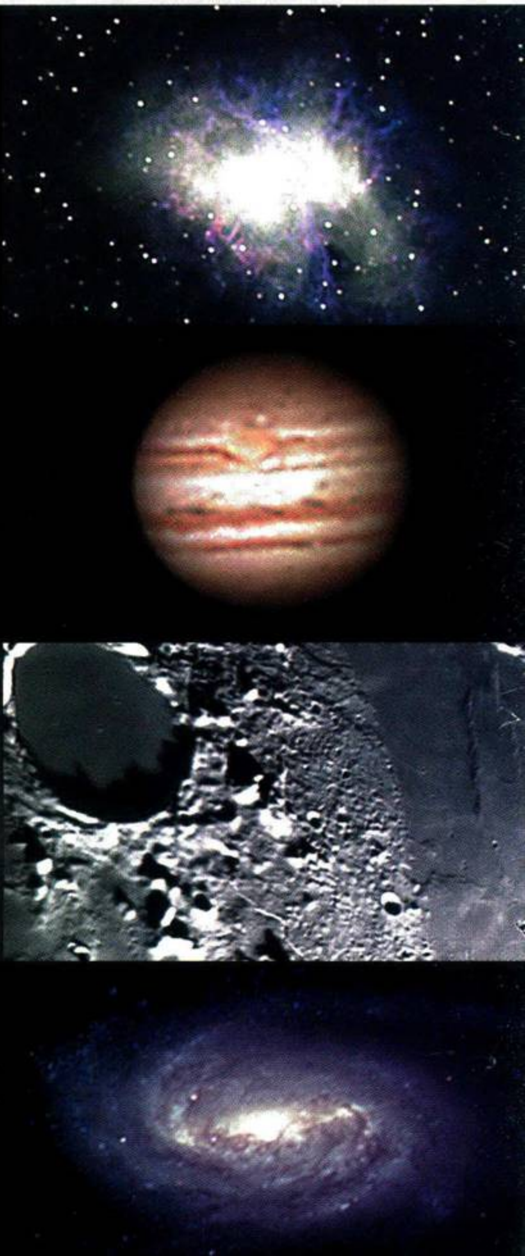


Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker; NGC 2903, 25" reflector, Jack Newton.



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For a limited time the Pictor 416XT includes **at no additional charge** the $800 Meade CCD Equipment System *(see photo),* with the **Meade Pictor 201XT CCD Autoguider** ($395); **Meade CCD Off-Axis Guider System,** with 1.25" and Schmidt-Cassegrain attachment barrels ($119); **Meade CCD Image-Orientation Adapter** ($35); **Meade Epoch 2000ip Image Processing Software** ($199); **Meade Deluxe Carrying Case** ($59).

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Pictor 416XT imagers are shipped at no additional charge with the $800 Meade CCD Equipment System.

All prices shown are suggested U.S. national mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable. ■ For safety reasons AC-powered personal computers should be used indoors only. ■ For your free copy of the 94-page **Meade 1996 General Catalog** write Meade Instruments or contact your authorized Meade Advanced Products Dealer.

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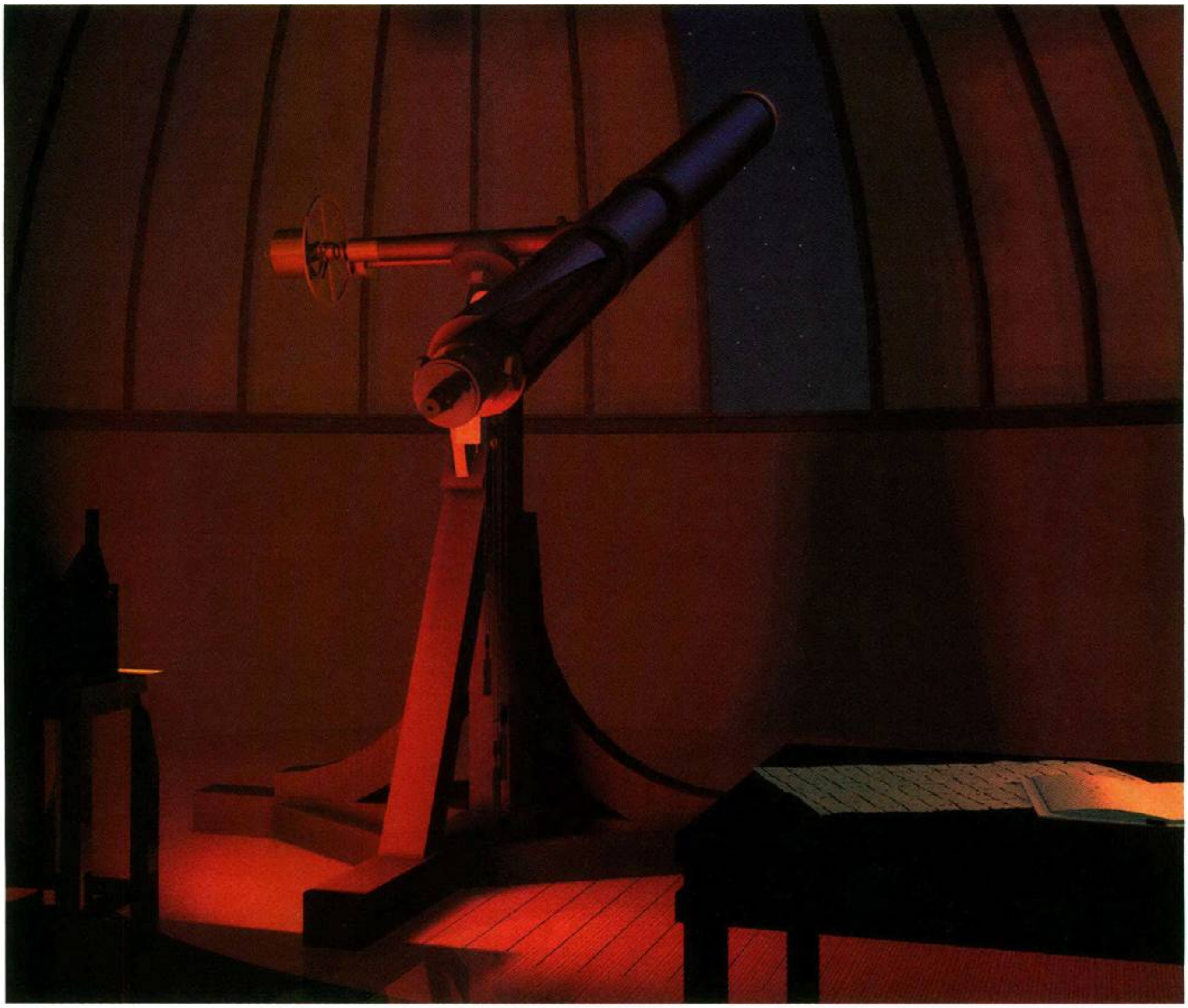

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Julian Baum

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The Excesses of Youth
They're young, hyperactive, and a mass of contradictions. T Tauri stars are the rebellious teenagers of the stellar world, and they provide a strong test for theories about how stars evolve. *Sally Stephens.*

Cover Art: Michael Carroll

42 Neptune's Discovery 150 Years Later
When this remote planet was spotted 150 years ago this month, it proved a triumph for Newton's laws of motion. But the search that led to the planet proved far from orderly. *William Sheehan and Richard Baum.*

50 Lunar Windows to the Heavens
Hubble's ultrasharp view from above the atmosphere has astronomers lusting for the ultimate high ground: the farside of the Moon. *Peter Bond.*

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A stellar month for observers features the full Moon being swallowed by Earth's shadow, creating a total lunar eclipse for all the Americas, and glorious Saturn at its best for the year. *Martin Ratcliffe and Alister Ling.*

U. S. Naval Observatory

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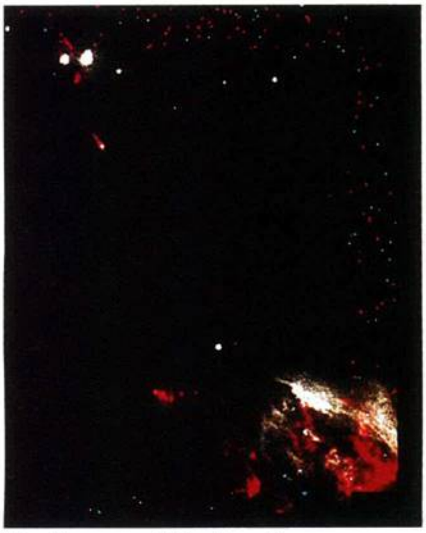
Scott Kenyon, et al. (CfA)

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68 Eclipse at Harvest Moon
This month's total lunar eclipse, the last for North Americans until 2000, will provide stunning views and great photo opportunities. *Alan Dyer.*

74 Faint Balls of Fire
The late summer sky offers a horde of globular clusters to challenge owners of large telescopes. *David Higgins.*

76 Discover the Autumn Sky
It's a myth that you *must* have a big scope to explore the universe. A 2- to 6-incher reveals countless wonders in the fall sky. *Glenn F. Chaple, Jr.*

82 Make Your Scope Light-Tight
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BEHIND THE SCENES

Astronomy in the Past, Present, and Future

Millions of stories arise in the pursuit of astronomy. Some are stimulating accounts of modern-day research and discovery. Others are fascinating narratives of little-known historical intrigue. And countless more anticipate how astronomy will unfold if scientific visionaries have their way. This month we offer a sampling from each of these time continua: astronomy in the past, present, and future.

We begin in the here and now with "Excesses of Youth," by Sally Stephens (p. 36). This dispatch from astronomy's front lines of research reports on emerging details of a special class of intemperate young solar-type stars, called T Tauri stars. New observations are helping astronomers hone their ideas about stellar development and what happens when these stars enter their rebellious "teenage" years.

Our following story, "Neptune's Discovery 150 Years Later," by William Sheehan and Richard Baum (p. 42), is an ironic tale of scientific triumph and human ineptitude from observational astronomy's glory days. The triumph was how a French mathematician and a German observer working together discovered the planet Neptune. The ineptitude was how British astronomers, through a combination of hubris, indifference, and evident blunder, missed the perfect opportunity to make the discovery themselves.

Finally, we cast an eye a decade or two into the future and consider what it would be like to do astronomy from the Moon. "Lunar Windows" by Peter Bond (p. 50) explores the viability, challenges, and benefits of establishing an observatory on the ultimate astronomical high ground.

Staff News

I'd like to take this opportunity to announce that associate editor Dave Eicher has been promoted to Senior Editor. Dave has had a long and fruitful career in astronomy, beginning when he founded *Deep Sky Monthly* in 1977 at the tender age of 15. He has been with ASTRONOMY magazine for fifteen years. With this promotion, Dave is taking on the editorship of ASTRONOMY's annual sky guide, *Explore the Universe '97*, which goes on sale September 3. This year's annual, says Dave, is more exciting and information-rich than ever. "*Explore the Universe* is the astronomy guide readers will want to keep handy all year. Comet Hale-Bopp of course gets big play along with all the other sky events of 1997."

ASTRONOMY: William Zuback

Dave Eicher

Dave is also the author of several successful Kalmbach books, most notably, *The Universe from Your Backyard*, and he has an asteroid named in his honor. In his "spare" time, Dave conducts research into Civil War history.

Sincerely,

Jeff Kanipe

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Managing Editor
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LX10 Electric Declination Motor System	**85.**
#2014 Magellan I Telescope Computer System for LX10, with 12,218-object database	**375.**

The 94-page Meade 1996 General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers. Prices shown are suggested U.S. mail-order prices.

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Compare *feature-for-feature* with other similarly priced Dobsonians!

- **Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass:** Unlike the plate glass optics of other Dobsonians that can become thermally unstable (especially in larger apertures), Meade Dobsonians are made of Grade-A, fine-annealed Pyrex—the exact same professional-quality optics used on Meade Starfinder Equatorials.
- **Precision Components:** Including a full-size rack-and-pinion focuser (1.25") with 2.6" travel and fully-adjustable *4-vane* secondary mirror system.
- **Rigid, Durable, Beautiful Dobsonian Mountings**, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the location and tracking of celestial objects.
- **Optical Tubes:** Starfinder Dobsonians include the same strong, spiral-wound optical tubes used on Starfinder Equatorials *(right).* All telescopes include a multi-coated MA25mm eyepiece; each tube is factory pre-drilled for the optional 6 x 30mm or 8 x 50mm viewfinder.
- **Performance!** A Meade Starfinder Dobsonian or Equatorial opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects—nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning, high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder equatorials may be used, in addition, for lunar and planetary photography and even for limited deep-space photography.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$39; 8"–$49; 10"–$69; 12.5"–$79. 16"–$45 packing, shipped truck freight collect.

ACCESSORY OFFER!

At the time you order any Meade Dobsonian, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, *and* the Meade #637 6 x 30mm viewfinder with metal bracket for a **total of $49.95!** *Purchased separately, the 2 eyepieces and viewfinder sell for $125.85!* Offer valid until further notice.

AUTHORIZED U.S. MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE COMPANY, Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
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STARF
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Immediate delivery!

Computerize your Meade® Starfinder Telescope for only $295!

Spend your time **observing, not searching** for objects! **With the incredible Meade Magellan™ Telescope Computer System** attached to your Meade Starfinder Dobsonian or Equatorial, finding any of **12,218 celestial objects** is almost as easy as pointing the telescope.

MEADE
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ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM
U.S.A.

Actual Size: 4" x 5" x 1.25"

- Don't spend $400, $500, or $600 for a computer system with fewer features! Designed and manufactured at the Meade Irvine facility, the Magellan I includes one of the largest object databases available, incorporates only premium-grade components, and sells for a low $295!
- **Easy to Use!** Just input the R.A. and Dec. of the object you wish to observe, or call up an object from Magellan's massive database. Magellan allows you to slew the telescope manually to the object and place it in the visual field, quickly and precisely.
- **Fast 2-Star Alignment:** Point the telescope at 2 bright stars selected from the star database, and the computer is aligned in *seconds.* No need to input time or date, latitude or longitude. Magellan's powerful microprocessor calculates telescope position in milliseconds and directs your movements of the telescope for fast, accurate object location.

Meade Magellan II Computer-Corrector for Starfinder Equatorials

Plug the Magellan II into the control panel of your Meade DC-powered Starfinder Equatorial *(right)* and you have *all the capabilities of the Magellan I (above)* **plus** a 4-speed, dual-axis, drive-corrector/microslewing system!

Includes: Magellan II hand controller *(right)* with 4 dual-axis speed rates (2x, 8x, 16x, 32x sidereal); high-resolution 4096-pulse encoders for both axes; electric Declination control system; 12,218-object computer database; 2-star alignment; RS-232 serial interface. (For Meade *DC-powered* Starfinder Equatorials, only.)

#2018: for Starfinder Equatorial 6", 8", or 10"	**$495.**
#2019: for Starfinder Equatorial 16"	**595.**

Prices plus $20 packing & shipping in the 48 states.

INDER
UTERS

■ **High-Resolution 4096-pulse Encoders:** Each Magellan system includes two premium-grade, high-resolution encoders. Encoder precision is 5.3 arc minutes.

■ **Large 32-Character LCD Red-Backlighted Display:** The same LCD display included with the Meade LX200 hand controller. Includes variable illumination from dim to bright.

■ **12,218-Object Database:** A database that includes an amazing array of objects:

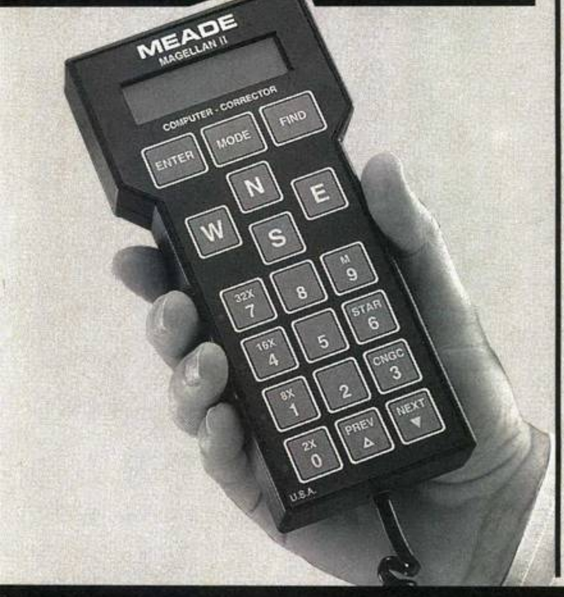
7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

■ **Supplied Complete!** With other computers you pay *once* for the basic controller and then pay *again* for the "Encoder Installation Package." Meade Magellan Systems are supplied **complete** with: controller/display unit (4" x 5" x 1.25"); encoders for both telescope axes; RS-232 serial interface; bracket for convenient placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan is ready to use. First-time installation is quick and simple.

Meade Magellan I Telescope Computer Systems

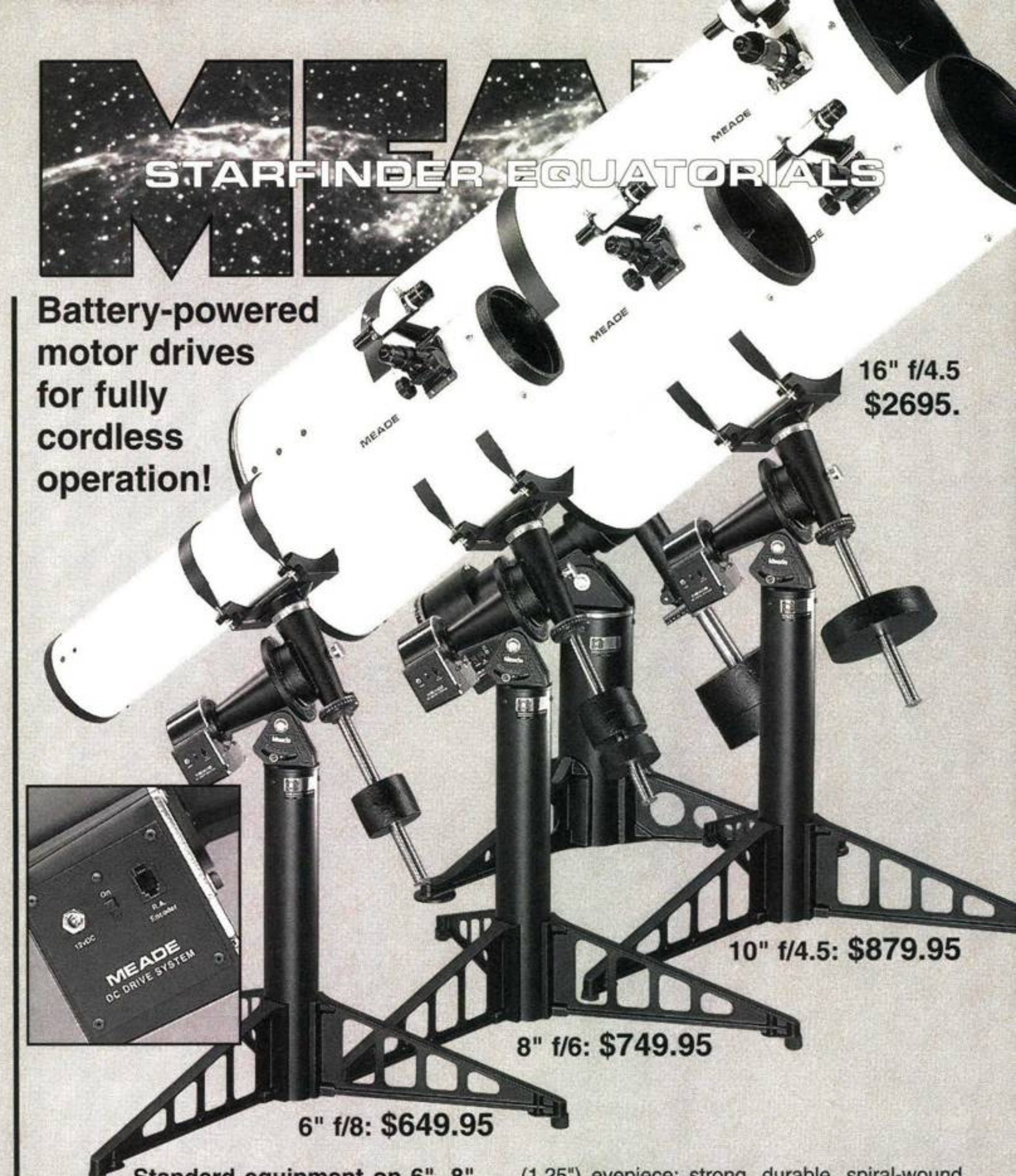
#2010:	**for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16"**	**$295.**
#2011:	**for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10"**	**295.**
#2012:	**for Meade (DC-powered) Starfinder Equatorial 16**	**295.**

All prices plus $15 packing & shipping in the 48 states. Prices shown are suggested U.S. national mail-order retail prices. For additional information on Meade Magellan systems, send for your free copy of the 94-page **Meade 1996 General Catalog.**



STARFINDER EQUATORIALS

Battery-powered motor drives for fully cordless operation!



16" f/4.5 $2695.

10" f/4.5: $879.95

8" f/6: $749.95

6" f/8: $649.95

Standard equipment on 6", 8", and 10" equatorial models includes:

■ **Superb Optical System:** Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

■ **Precision Equatorial Mount:** Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

■ **Battery-Powered Cordless Drive System!** Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries inserted through the drive cover. Control panel *(see inset photo, above)* also permits powering of telescope from 12v. auto cigarette lighter plug, using optional 25' cord.

■ **Accessories and Components:** Rack-and-pinion focuser (1.25") with 2.6" travel; #637 6 x 30mm viewfinder; multi-coated MA25mm (1.25") eyepiece; strong, durable, spiral-wound optical tube with attractive white finish.

■ **Starfinder Equatorial 16:** Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6"-dia. pier, 6 x AA-size battery-powered worm gear drive, 8 x 50mm viewfinder, #682 giant (2" & 1.25") rack-and-pinion focuser.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$65; 8"–$75; 10"– $90. 16"–$55 packing, shipped truck freight collect.

To Order: Contact your authorized Meade Advanced Products Dealer. All prices shown are suggested USA mail-order retail prices.

Free 94-page Meade 1996 General Catalog is available from your authorized Meade dealer or directly from Meade Instruments.

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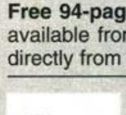

At the time you order any Meade Starfinder Equatorial Telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, for a **total of $29.95!** *Purchased separately, the 2 eyepieces sell for $75.90!* Offer valid until further notice.

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Meade Instruments Corporation

World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur

16542 Millikan Avenue, Irvine, Calif. 92714 ☐ (714) 756-2291
FAX: (714) 756-1450

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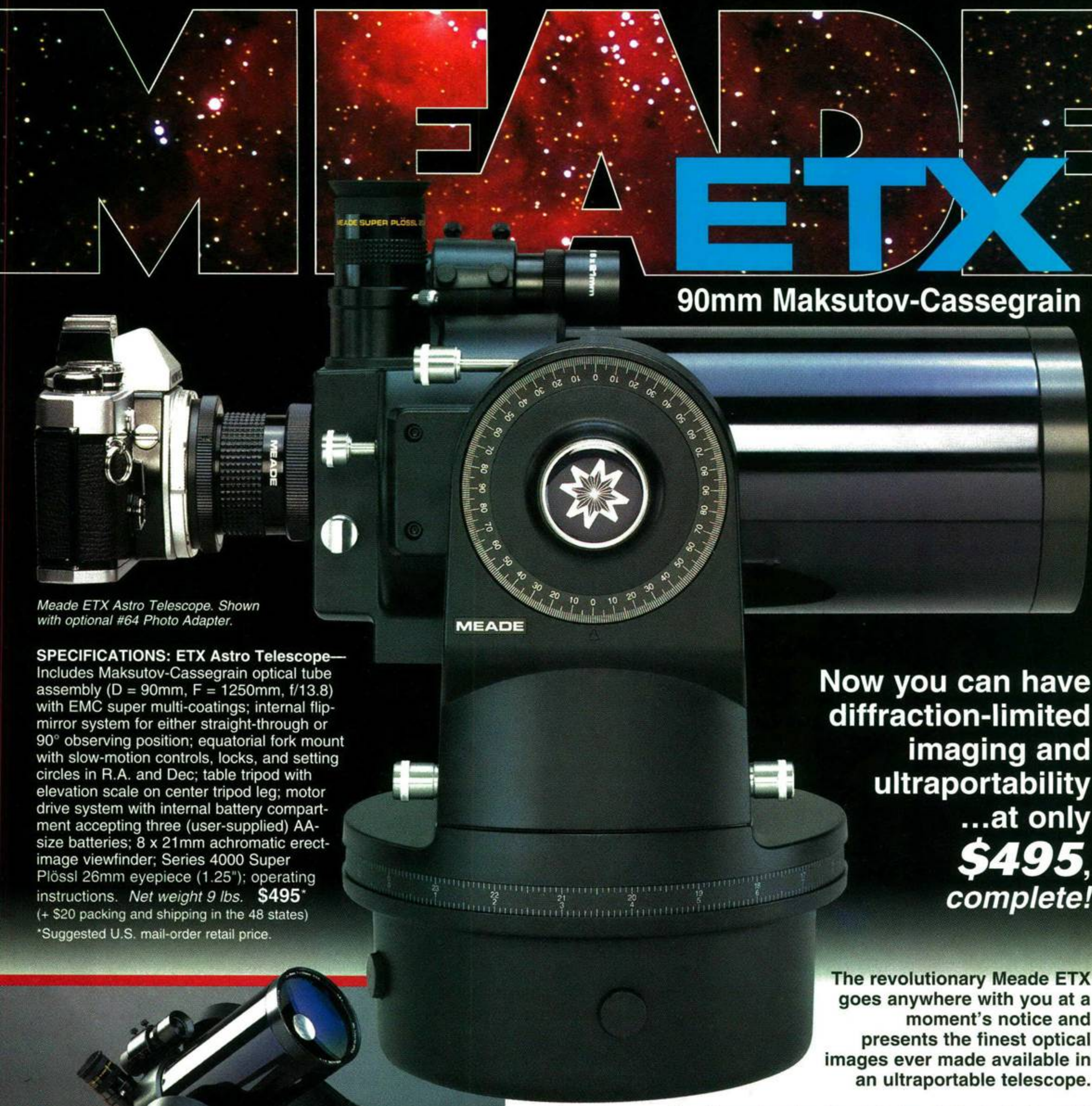
MEADE ETX

90mm Maksutov-Cassegrain



Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.* **$495***
(+ $20 packing and shipping in the 48 states)
*Suggested U.S. mail-order retail price.

Now you can have diffraction-limited imaging and ultraportability ...at only *$495*, *complete!*

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds,* just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
16542 Millikan Avenue, Irvine, Calif. 92714
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MEADE

EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 3000™ Plössls 50° field; multi-coated

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930**, each: **$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

HOW TO ORDER

- Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

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Orders: 800-621-2248; Info/IL: 312-332-2000.

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ASTRO LETTERS

Before the Big Bang

Michio Kaku's "What Happened Before The Big Bang?" (May 1996) proclaimed that other universes may exist. If the Big Bang happened, then the explosion had to be the most uniform thing that ever occurred. This uniformity should exist within the distribution of stars and galaxies.

The universe appears uniform in many ways. However, why should groups of galaxies exist in the wake of the uniformity that followed the Big Bang? There must be another portion of the universe that is yet undiscovered beyond what we now comprehend about the cosmos. — *Wendell P. Hooper, Green Mountain, North Carolina*

I found Michio Kaku's article on quantum cosmology well written and thought out. I think readers may have missed one central concept: in physics, some ideas *are* pursued for their beauty with experimental verification coming later. The article tied together work by other eminent physicists.

I hope ASTRONOMY will not patronize its readers by ceasing to run such thought provoking articles. — *Robert Puharic, Whitehall, Pennsylvania*

Just What is Smalt, Anyway?

Mr. Ling's monthly columns are usually the first thing I read in ASTRONOMY each month. He quotes the term "smalt" (July 1996) and questions its definition. Smalt is a fused mixture of cobalt oxide, silica, and flux — A sort of cobalt glass which is ground into a powder and used as a glaze ingredient to produce a rich, blue-jean blue color. Smalt is the color of the Albireo companion in the photograph on page 63. — *Steve Irvine, Wiarton, Ontario, Canada*

Money Was Well Spent

I feel compelled to respond to Roger J. Hoffman's letter (March 1996) chiding you for selecting a $3,000 telescope for a "beginner." After long and hard hours of studying and viewing the heavens through binoculars, we chose to spend our $3,000 on a telescope. We were serious enough to invest in what we wanted rather than buy less and anticipate upgrading at a later time. This decision has been a good one. — *L. Glenn and Barbara J. Peck, Livingston, Texas*

Enjoying the Human Side of Astronomy

I enjoyed your article on Edward Emerson Barnard (June 1996). I would like to see more of the "human" side of astronomy presented in your magazine. Because the photographs in ASTRONOMY represent the work of many dedicated amateur astronomers, I think ASTRONOMY should run stories about these individuals. — *Joseph B. Whitebread, Jr., McLean, Virginia*

The Votes Are Coming In:

(In the July 1996 issue of ASTRONOMY, Robert Naeye, associate editor, invited readers to vote "Yes, other civilizations exist in the Milky Way Galaxy" or "No, we are alone in the Milky Way Galaxy." As of press time, we had received about 900 votes and the ratio stands four to one in favor of the existence of other civilizations.

Yes, There Are Others

I have followed the question of intelligent life in our Galaxy for many years. I've come to see this issue more as a matter of biology than of astronomy. My tentative conclusion is yes, there is intelligent life elsewhere in our Galaxy, but it is rare. — *Thomas R. Willmitch, Gov. Aker Observatory, Safford, Arizona*

The facts presented have changed my thinking. While I still vote "Yes," I now believe that the numbers of such civilizations are much smaller than I previously believed. With some 200 billion stars residing in our Galaxy, surely a few have planets similar to Earth. — *Doug Tracy, Toledo, Ohio, DPTracy@aol.com*

Yes, I strongly think there are other intelligent civilizations in the Milky Way Galaxy. I strongly believe that life will find a way. Lichen and mites live in Antarctica. Mold, I

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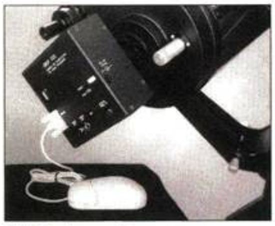

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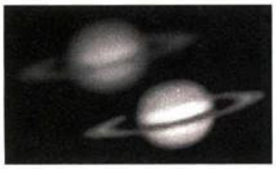

Saturn, before and after enhancement.
Pale cloud bands snap into view

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NGC5139 90mm f/4, 2x25 seconds with *SCD*

M82 otherwise invisible in badly light polluted skies. 90mm f/4 with *SCD*

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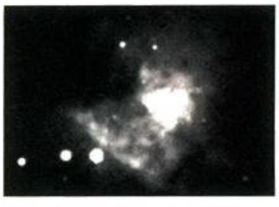

M42 in Orion, 4 x 4 seconds, 8" f/10

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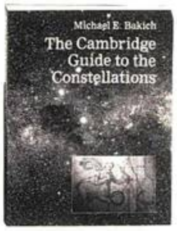
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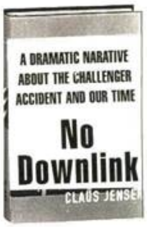
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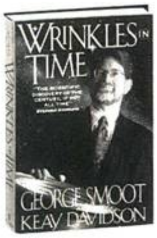
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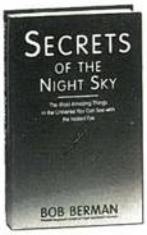
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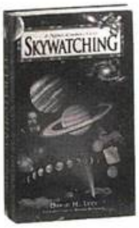
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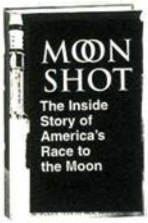
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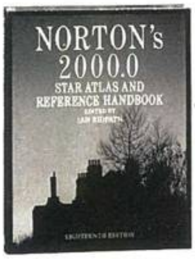
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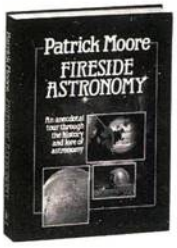
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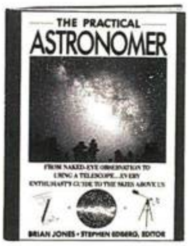
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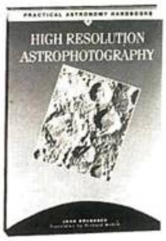
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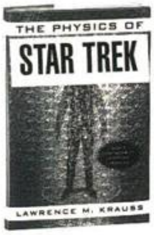
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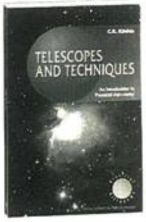
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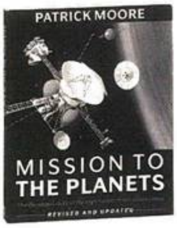
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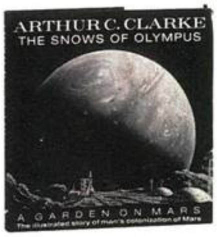
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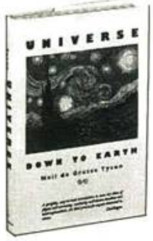
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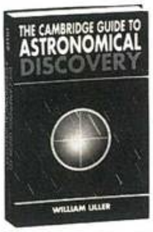
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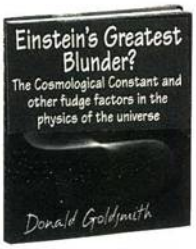
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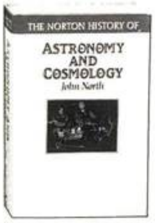
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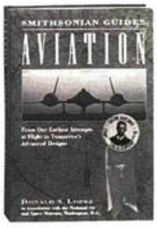
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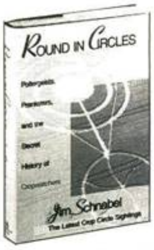
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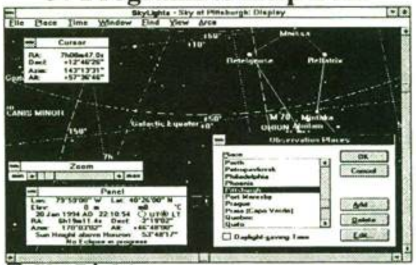

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believe, lives in the boiling waters at Yellowstone. I think that life does not have the stringent requirements that most believe. And where there is life, there is evolution.

Where there is evolution, sooner or later, there will be intelligence. — *Carlton Guidry, La Porte, Texas*

This sort of anti-Copernican speculation may be beside the point. Historic argument over the existence of a Northwest Passage, for instance, could never be settled by thought experiments alone. Someone had to embark on an exploratory observation. In the matter of intelligent cosmic company, speculation is at least thousands of years old. It would be extremely myopic to be disheartened by mere argument now. We finally have the capability of doing the observations. — *Seth Shostak, Public Programs Scientist, SETI Institute, Mountain View, California*

— Robert Naeye responds: I agree wholeheartedly with Dr. Shostak. As I stated in the article, SETI represents an inexpensive, experimental approach to this profound question.

To learn more about SETI, check out the following home pages:

The SETI Institute's web site: http://www.seti-inst.edu/

The Planetary Society's Project META and BETA can be perused at: http://wea.mankato.mn.us:80/tps/meta_be.html/

U.C. Berkeley's Project SERENDIP is reachable at: http://albert.ssl.berkeley.edu:80/serendip/

No, We Are Alone

Your points are logical and clear, and more importantly, match the available evidence. Thanks for being willing to say the unthinkable and venture in your own right to "where no (scientist) has dared to go before." — *Dale Foust, Cedar Rapids, Iowa, Shbug01@aol.com*

I think that life itself is quite common. Intelligent life, however, is another matter entirely. It's a long way from bacteria to intelligent organisms and there are several biochemical and evolutionary "choke points" along the way. As for the development of intelligence itself, it is only one of many evolutionary strategies and so far has appeared in full bloom on Earth only once; recently, at that, though mollusks such as octopi and squid come quite close.

I doubt that many technological civilizations exist, if any at all. I hope to eat my words some day, because any such contact would give us an entirely new perspective on everything from technology and biology to religion and economic and social systems. — *Dr. Roger Sauterer, Jacksonville State University, Jacksonville, Alabama*

I believe human beings are a very special phenomenon in the Galaxy. Would it not be ironic to find out that we are alone, and the entire Galaxy is just waiting for exploration? Perhaps it would be more ironic if we as Homo Sapiens destroy ourselves and in the last days of our existence realize how special we were, how far we could have evolved, and how much we could have discovered. — *Jeffrey W. Scott, Ramstein, Germany, 100527.3430@CompuServe.com*

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NASA provides a web site that allows the public to participate in all shuttle missions. Please join us at: http://shuttle.nasa.gov/. We also have a new server emphasizing the "Liftoff Academy," which discusses various space-related topics including living on board the shuttle and the planned International Space Station. This site is located at: http://liftoff.msfc.nasa.gov. —*Becky Bray, Liftoff Administrator, Marshall Space Flight Center, Huntsville, Alabama, becky.bray@msfc.nasa.gov*

Correction

"Spirals Show Their Dusty Disposition," (AstroNews, June 1996), should have mentioned Christopher Conselice, University of Chicago, as part of the team of astronomers whose findings were presented at the January 1996, American Astronomical Society meeting. □

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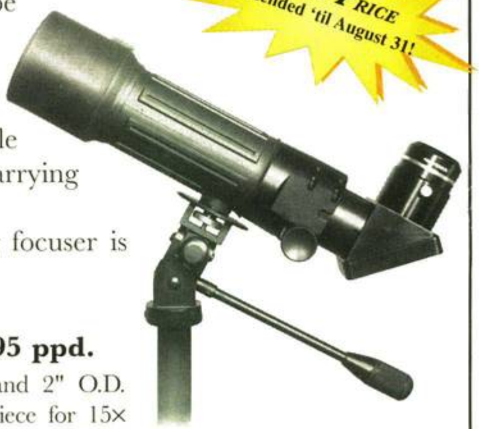

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The Lost Ring of Saturn

by Richard M. Baum and Thomas A. Dobbins

Ninety-seven years ago the French astronomer Camille Flammarion used a 10¼-inch refractor to observe Saturn and found the planet's A Ring had an unusual, diffuse appearance. Although Flammarion's writings on astronomy had elevated him to celebrity status, little notice was taken of his remarks at the time. In retrospect, however, his report set the stage for a series of observations that remain controversial.

In 1907, when Saturn's rings were edgewise, the eminent French observer Georges Fournier used an 11-inch refractor to spy the planet and glimpsed "a sort of nebulous, corpuscular cloud enveloping the ring on both faces." In the ansae of the very narrowly opened rings this "very pale luminous zone" appeared to extend for a short distance beyond the extremities of the A Ring.

Another observation of this peculiar phenomenon came in October 1908 with the new telescope at the Geneva Observatory. The instrument, a 16-inch Cassegrain reflector, was trained on Saturn. Only 10 months had elapsed since Earth had last passed through the plane of the rings, so they appeared inclined little more than 5° to an earthbound observer.

Schaer noticed something unusual. Where the rings passed in front of the globe, their outer edge appeared to have a narrow, dusky halo. At first he thought this was merely a poorly resolved border between the outer edge of the A Ring and the shadow cast by the rings on the globe, or perhaps even one of Saturn's atmospheric belts. With increased magnification, he could trace the dusky band beyond the confines of the globe and see it against the dark sky background. In the steadiest moments, he glimpsed it almost halfway to the extremities of the rings before losing it in their glare. In equally good seeing on the following night, Schaer was able to distinguish a pencil-thin strip of light reflected by the planet's cloud canopy separating the jet-black shadow of the ring on the globe from a dusky band about 1" wide bordering the outer edge of the A Ring. He arrived at an "almost absolute certainty that the bright rings are towered by an exterior dark ring."

Across the Atlantic, Schaer's ring was confirmed by Professor David Todd with the 18-inch Brashear refractor at Amherst College. Such was not to be the case, however, when the news reached Edward Emerson Barnard, arguably the foremost observational astronomer in the United States. (See "E. E. Barnard's Magnificent Milky Way," June 1996.) On two evenings in January 1909, Barnard carefully examined Saturn with the 40-inch Yerkes refractor at Williams Bay, Wisconsin, the largest instrument of its kind in the world. By now, three and a half months past opposition, Saturn rode low in the southwestern sky at nightfall. Not surprisingly, seeing was so mediocre that Barnard was prompted to stop-down the aperture slightly to improve definition. He saw "nothing abnormal anywhere."

Visual discoveries of a dozen comets, several nebulae, and the fifth satellite of Jupiter had earned Barnard a reputation as a remarkably keen-eyed detector of faint objects, which Schaer's ring was alleged to be. So great was the esteem for Barnard's skill as an observer, combined with the fact that he had employed the world's greatest telescope, that his pronouncement was widely accepted as the final word on the subject of Schaer's ring, which was soon relegated to obscurity.

In 1919, however, indirect evidence for an exterior ring was provided by an eclipse of Saturn's satellite Iapetus by the shadow of the planet's rings. On February 28, W. F. A. Ellison observed Iapetus emerging from the shadow of the A Ring with the 10-inch Grubb refractor of Armagh Observatory in Ireland. The unexpectedly gradual brightening of Iapetus was not completed until some 13 minutes after the predicted time of the end of the eclipse, suggesting that the ring system extends farther than was generally supposed.

By the early 1950s, still several years before the dawn of the space age, professional astronomers focused far beyond the confines of the solar system. Except for a veritable handful of specialists, monitoring the planets was left to amateur observers. The rings of Saturn were once again obliquely inclined in an almost identical fashion to their presentation at the time of Schaer's 1908 observations. Perhaps coincidentally, a spate of sightings of an exterior ring followed. In Chester, England, in April 1952, one of the authors, Richard Baum, reported a feature near the limits of visibility much like that described by Schaer. With a variety of instruments ranging from a 4½-inch Cooke refractor to a 9-inch Newtonian, Baum detected the ring on several occasions during the next two years.

From halfway around the world came reports by two prominent members of the Association of Lunar and Planetary Observers, Thomas R. Cave, Jr., and Thomas A. Cragg. As with Schaer, Cave's first clue to the presence of the feature was an unusual dusky appearance exhibited by the edge of Ring A where it crossed the ball of the planet. Cave related his suspicions to Cragg, a solar observer at Mount Wilson Observatory near Los Angeles. He saw the feature as "duskier than the Crepe Ring, about ⅓ as bright and ⅓ to ½ as wide, brightest portion about ⅔ of the way out, apparently joined to the A Ring without a division." Walter Haas, the founder of the Association of Lunar and Planetary Observers, suggested the provisional designation "Ring D."

Confirmation was scanty. The late Charles F. Capen, a renowned Mars specialist and prolific photographer of the planets, glimpsed the elusive exterior ring on the night of May 4, 1954, with the 24-inch Clark refractor

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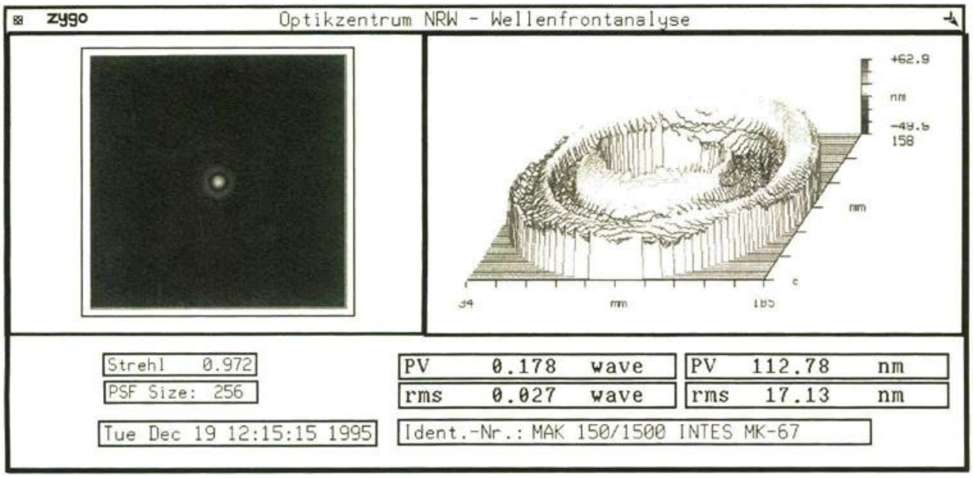

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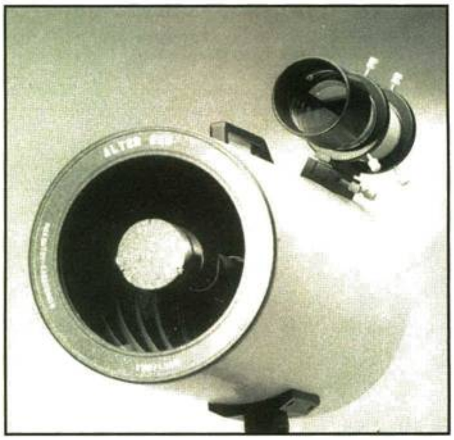

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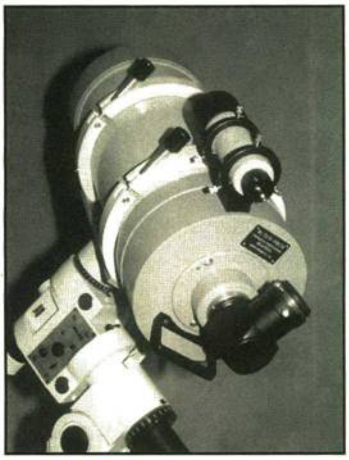

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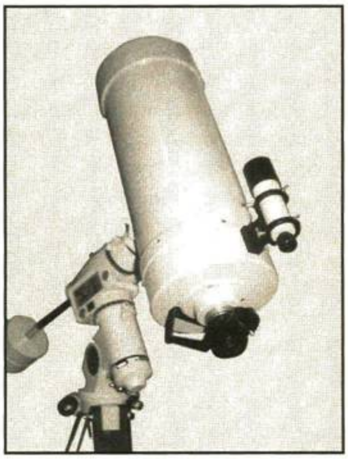

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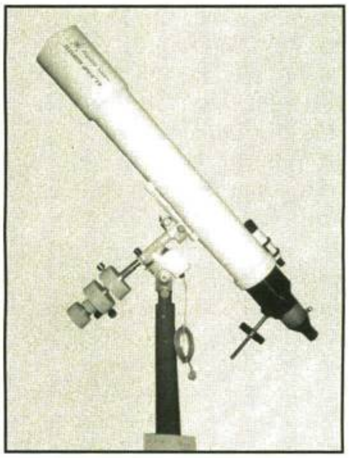

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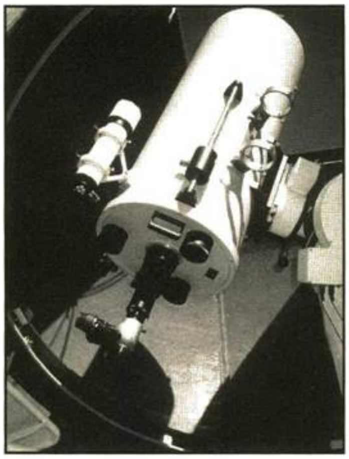

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of Lowell Observatory. German astronomer Walter Feibelman photographed the planet in 1966. "It is known that when seen nearly edge-on," he wrote, "the A ring, normally fainter than the B ring, can sometimes appear brighter than B. Similarly, an outer 'D' ring might appear relatively bright at the time, while when in the open position it may be completely unobservable."

Two of his plates recorded extremely faint hairlines emerging from the glow of the grossly overexposed image of the planet and its known rings. Extending to more than twice the previously accepted diameter of the ring system, Feibelman's exterior ring candidate was very tenuous, with only about one-millionth the brightness of the A Ring. But it did lend a new air of plausibility to the earlier reports by Schaer and other visual observers. Only a much closer inspection by spacecraft promised to shed further light on the mystery.

In September 1979 the Pioneer 11 space probe flew past Saturn's rings at a distance of less than 21,000 miles, returning tantalizing images of a ring centered just 2,400 miles beyond the outer edge of the A Ring. Named "Ring P" by the Pioneer imaging team (in their nomenclature "Ring D" was the designation given a very tenuous ring that extends front the inner edge of the Crepe ring down to Saturn's cloud tops), it was so narrow that the probe's imaging polarimeter could not resolve it. It was also extremely faint, with less than 1/10 the mean optical density of the tenuous Crepe Ring. Despite a location that coincides perfectly with the location of Schaer's ring, such a meager wisp of light could not possibly have been detected by a telescopic observer. The Voyager spacecraft found that the P Ring contains particles of about a micron in diameter, like the motes of dust in a sunbeam. Particles this tiny are subject to drag from the pressure of impinging photons of sunlight and from collisions with charged particles in Saturn's magnetosphere, rapidly losing energy and spiraling downward toward the globe of the planet. The smallest particles in the F Ring must be of recent origin, as little as 20 years old by some estimates.

An emerging consensus supports the view of Lowell Observatory's Eugene Shoemaker that the rings of Saturn are not primordial leftovers from the days of the formation of the planets, but are instead the short-lived products of an ongoing process of creation and destruction. The untold thousands of moonlets embedded in the rings of Saturn are the likely source of material for the youthful rings we see today, requiring only collisions with one another or with a passing meteoroid or comet to give birth to new rings.

Did such a collision occur at the dawn of this century, creating an exterior ring of which the bizarre F Ring that we see today is but a remnant that continues to evolve? The prominent A Ring consists of the remnants of a satellite only about 30 miles in diameter. The more delicate feature described by Schaer, therefore, would have suffered a rather minor catastrophe.

The Saturn revealed by the Voyagers vindicated many telescopic observers who had seen the planet under superb conditions with good instruments but whose reports had been greeted with skepticism and even ridicule. The principal rings really were "minutely subdivided into a great number of narrow rings" as George Bond of Harvard College Observatory had claimed in 1851. The Cassini Division really was "not devoid of material" as Camille Flammarion had alleged in 1899. Most improbably, even the ephemeral radial spokes first reported in 1896 by Eugene Antoniadi proved to be only too real. Perhaps Schaer and his successors did witness a transient phenomenon in a ring system more complex than anyone dared to imagine. □

Richard M. Baum and Thomas A. Dobbins are experienced planetary observers. Baum coauthored "Neptune's Discovery 150 Years Later" (page 40).

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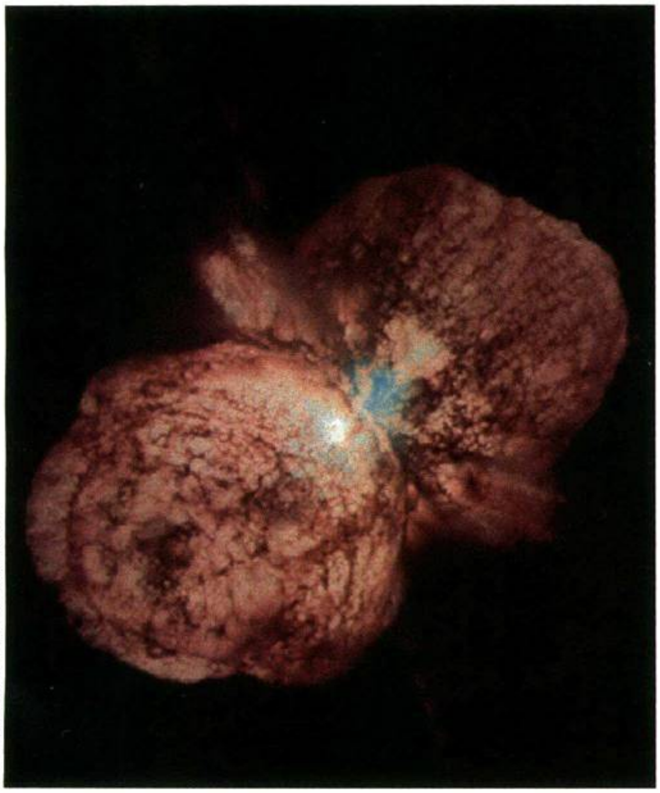
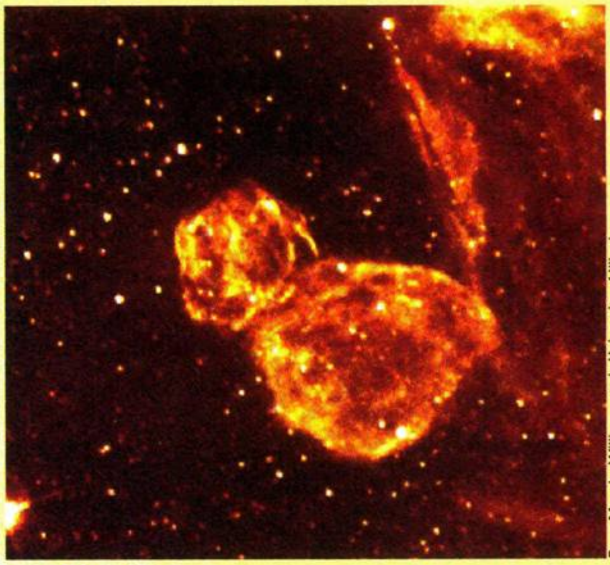
New View of Doomed Star

In the 1840s this star, Eta Carinae, was the second-brightest star in the night sky after mighty Sirius. Now it's just another ho-hum 6th-magnitude star barely visible to the unaided eye.

In the new Hubble Space Telescope image, twin lobes of gas and dust are seen expanding away from the central star at 700 km per second. An explosive event caused by some as-yet unknown mechanism ejected the lobes, causing the flare-up visible in the 1840s. The distance from end-to-end is half a light-year. Between the lobes is a disk of gas that was ejected in a less violent outburst visible in the 1890s. University of Colorado astronomer Jon Morse used image processing techniques to bring out details only 16 billion kilometers across, which is a little more than twice Pluto's distance from the Sun. Eta Carinae is 100 times more massive than the Sun and four million times more luminous; only a handful of supermassive stars like Eta Carinae are known in the Galaxy. The star will eventually become a supernova. If you have a pair of 3D glasses, check out the following web site: http://www.stsci.edu/pubinfo/PR/96/23/C.html.



Jon Morse (Univ. of Colorado) and NASA



Rosa Murphy Williams et al., University of Illinois

Cosmic Demolition. The supernova remnant DEM L 316 in the Large Magellanic Cloud consists of two distinct bubbles colliding in space. Last June astronomers announced that these bubbles are from two supernova explosions. This unique object provides the opportunity to study how exploding stars scatter heavy elements into the cosmos. Supernova remnants are relatively rare and short-lived, and finding two that exploded so closely at nearly the same time is an amazing find.

A New Planet in Bootes

The planet-hunting team of Geoff Marcy and Paul Butler have discovered their fourth extrasolar planet in less than six months. The new planet orbits the 4.5-magnitude star Tau(τ) Bootis, which is about 60 light-years away. The planet has a minimum mass of 3.87 Jupiters and orbits the star in a circular orbit every 3.3 days. The planet lies a mere 6.9 million kilometers (0.046 astronomical unit) from Tau Bootis, making it closer to its parent star than any other planet discovered to date. Tau Bootis is an F7 star, meaning it is slightly larger and hotter than the Sun.

The planet's exceptionally short orbital period is similar to those of the planets orbiting 51 Pegasi and Rho^1 Cancri (see "Another Extrasolar Planet," AstroNews, July 1996). All three stars have relatively high abundances of elements heavier than hydrogen and helium. "There's a real hint of a correlation, but what that correlation means is not known," says Butler. "These 51 Peg-like planets were completely unexpected."

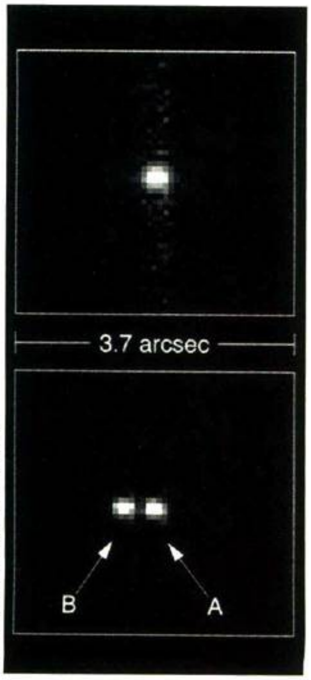
Marcy and Butler have finished their initial analysis of the 120 stars on their observing list. Butler says they have now discovered all the planets that were easy to detect. While they have several other good candidates, Butler doubts they will have enough solid data to announce more detections before the end of 1996. "There won't be anything like this again. Probably by the end of the year we will drop back to announcing a few planets per year rather than a whole flush of them," he says.

A Brown Dwarf in the Neighborhood?

A team led by Alfred Schultz and Helen Hart of the Computer Sciences Corporation has aimed the Hubble Space Telescope at two nearby star systems to look for substellar companions. One of the two, Wolf 359, appears to be solitary. Wolf 359 is only 7.5 light-years away; only the Alpha Centauri triple star system and Barnard's star lie closer.

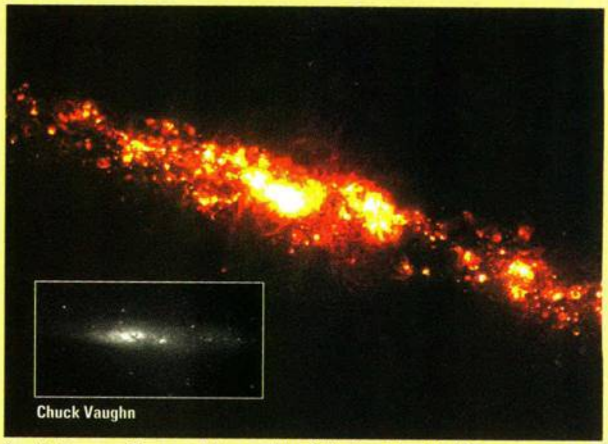
Hubble appears to have had better luck with Wolf 424, 14 light-years away. Ground-based images had previously revealed two objects in this system separated by about the same distance that Mars orbits the Sun. Astronomers thought that one or both objects could be brown dwarfs, but the mass estimates of the two objects were highly uncertain.

By combining recent Hubble observations with the previous ground-based observations of the system's orbital motion, Schultz and Hart calculate the combined mass of the two objects to be between 0.14 and 0.20 solar mass. The brighter of the two, Wolf 424A, appears to be about 13 percent more massive than its dimmer companion, Wolf 424B. Unless the total mass of the system is near the upper limit, Wolf 424B doesn't have enough mass to burn hydrogen in its core. This probably puts Wolf 424B into the realm of brown dwarfs. "There is a possibility that both components are brown dwarfs," says Schultz, who notes that more Hubble observations are needed to pin down the exact nature of both objects.



Alfred Schultz (CSC), et al. and NASA

Wolf 359 (left) appears to be a single object. But Wolf 424 (right) contains two objects, with the one on the left probably being a brown dwarf.



Annette Ferguson, Rosemary Wyse, and Jay Gallagher, Johns Hopkins

Supergiant Gas Plumes in NGC 55. Huge filaments, loops, and bubbles of hydrogen gas possibly formed by supernovae litter the disk of the edge-on galaxy NGC 55 in Sculptor. Astronomers released this image, made with a 1.5-meter telescope at Cerro Tololo in Chile, last June. The portrait shows how massive stars in the galaxy's disk are shaping and evolving the structure as a whole. Inset: NGC 55 as photographed with a large backyard telescope.

Extrasolar Planet Update

The nearby star Lalande 21185, only 8.25 light-years away, might be orbited by two planets instead of one, reports University of Pittsburgh astronomer George Gatewood (see "A Nearby Extrasolar Planet? AstroNews, August 1996). Slight changes in the star's velocity indicate that a Jupiter-mass planet might be orbiting at a distance equivalent to Saturn's distance from the Sun. But Gatewood is now reporting that a second planet, perhaps slightly less massive than Jupiter, might be orbiting closer in, at about the distance of the asteroid belt in our solar system. If confirmed, Lalande 21185 would be the first normal star other than the Sun known to be orbited by more than one planet.

The companion to the star 51 Pegasi is almost certainly a planet rather than a low-mass star in a highly inclined orbit, argues a team of astronomers led by Caltech's Steven Pravdo. The star and its companion are separated by only ⅛ the Mercury-Sun distance. The team notes that all binary star systems with similar separations exhibit high X-ray emission, whereas 51 Pegasi's X-ray emission is typical of a single, solar-type star. Moreover, tidal interactions with a nearby stellar-mass companion should have speeded 51 Pegasi's rotation velocity to match the companion's 4.2-day orbital period. But 51 Pegasi rotates once every 30 days, strongly suggesting that its companion's mass is well below that of a star.

In other planet news, Edward Guinan, George McCook, and Steve Wright of Villanova University are reporting a possible planet orbiting the eclipsing binary star system CM Draconis, about 50 light-years away. On June 1 the team observed a 0.08-magnitude drop in the system's luminosity that could be explained by a planet with roughly 85 percent Jupiter's diameter passing in front of one of the stars along our line of sight. The two M dwarf stars each contain only ⅕ the mass of the Sun and orbit a common center of gravity once per day. The purported planet would orbit around both stars much farther out, and would take sev-

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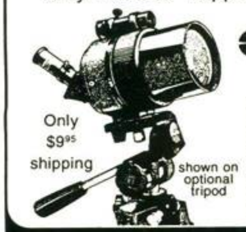
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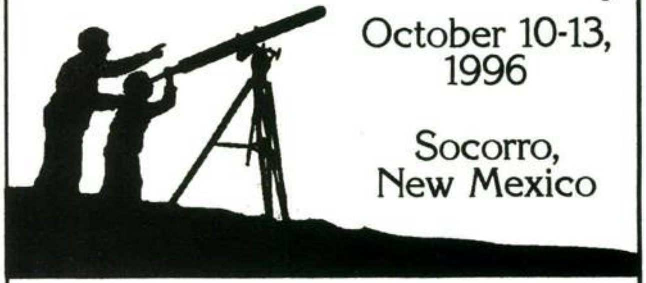

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eral months to complete one circuit. "This is a very tentative result that needs to be confirmed by more observations," says Guinan. If it is a planet, it would be the first planet known to orbit a tightly separated binary star.

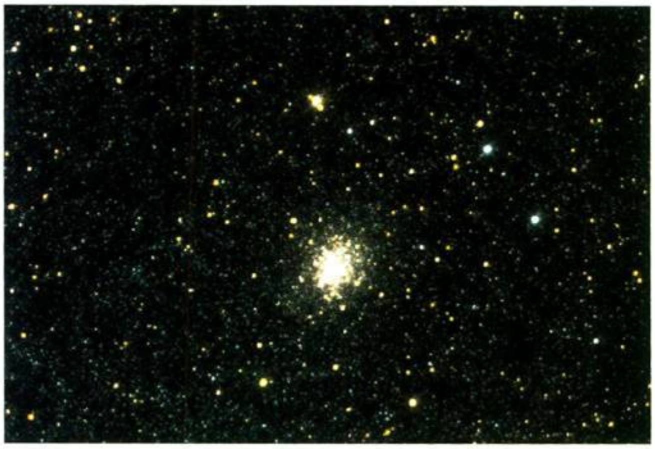
Adler Celebrates Astronomy in Art

The evolution of astronomy, captured through the imagination of artists and spanning three centuries of astronomical art, is demonstrated in a comprehensive art exhibit at the Adler Planetarium and Astronomy Museum in Chicago, Illinois, from July 20–October 20, 1996.

ASTRONOMY Magazine is cosponsoring the event titled, "Imagine the Universe: A Space Art Exhibition." The exhibit features works by Chesley Bonestell, Don Davis, Bill Hartmann, Jim Hervat, Ron Miller, Joe Tucciarone, and Mark Paternostro, curator of the show.

Additionally, selected rare astronomical works on paper from the Adler Planetarium's History of Astronomy Collection will be exhibited.

The Adler Planetarium and Astronomy Museum is located at 1300 S. Lake Shore Drive. For more information, call (312) 322-STAR.



Ata Sarajedini (Kitt Peak) and NASA

Bill and Sally Fletcher

By analyzing globular clusters like this one orbiting M33 (top), astronomers have determined that M33 (bottom) is 5 to 10 billion years younger than the Milky Way.

M33 Younger than the Milky Way

The Hubble Space Telescope's amazing resolution allows astronomers to see details in globular clusters belonging to other galaxies (see "Hubble's Birthday Bash," August 1996). Recently a team led by Kitt Peak astronomer Ata Sarajedini imaged eight globulars belonging to the spiral galaxy M33, located 2.4 million light-years away in Triangulum. M33 is the third most massive member of the Local Group of galaxies, coming in behind the Andromeda Galaxy (M31) and the Milky Way.

Surprisingly, M33 appears to be 5 to 10 billion years younger than its two more massive neighbors. Sarajedini's team analyzed star colors in the eight globulars. Young globulars tend to have red helium-burning stars, whereas these stars appear blue in older globulars. Compared to globulars orbiting the Milky Way and M31, the helium-burning stars in M33's globulars were significantly redder, strongly suggesting a youthful age.

"M33 just seems to have sat around for a few billion years before it started to form the bulk of its stars," says Sarajedini. "Perhaps it encountered some other galaxy with which it interacted, and this interaction caused it to start forming stars."

Fastest X-ray Gun in the West

Astronomers using the Rossi X-ray Timing Explorer satellite have discovered an X-ray source that switches the energy of a thousand Suns on and off 1,130 times per second. This rate of oscillations was 10 to 100 times faster than any previously known source.

Even before the launch of the RXTE in December 1995, astronomers knew that the source, called Scorpius X-1, was by far and away the brightest source in the X-ray sky. But previous X-ray satellites didn't have the ability to detect such rapid oscillations. The RXTE has since found two other rapidly oscillating X-ray sources that turn on and off 900 and 1,100 times per second.

Astronomers think all three oscillating sources are binaries consisting of a neutron star and a normal star. A neutron star's powerful gravity pulls gas off its companion, which flows onto the neutron star at near-light speed. When the gas reaches the neutron star, it heats up to more than 10 million degrees Celsius and emits X rays. "The oscillations seem to depend on the energy of the X rays and on the rate at which gas is falling onto the neutron star," says Tod Strohmayer of the Universities Space Research Association. But Michiel van der Klis of the University of Amsterdam in the Netherlands adds, "We are still figuring out how to explain all this in detail."

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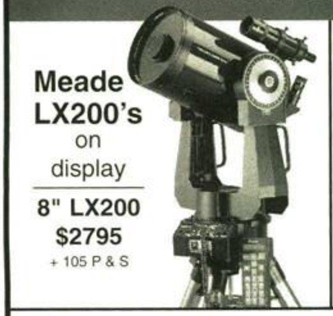

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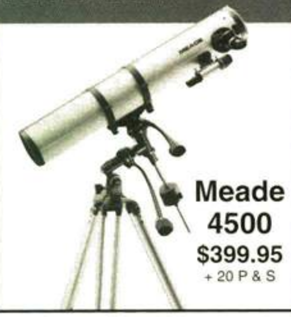

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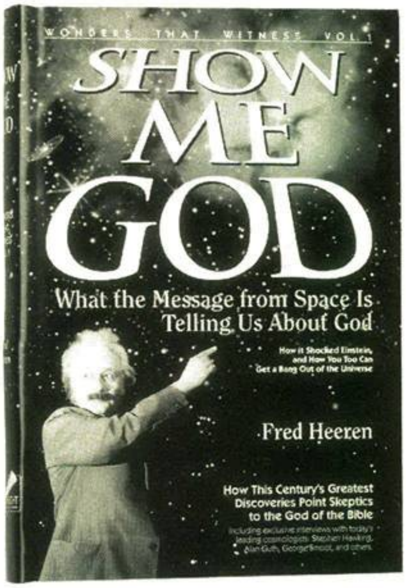
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AMATEUR NEWS

Sizzling Days and Clear Nights at TSP

Clear skies and starlit nights were the norm at this year's Texas Star Party (TSP), held on the Prude Ranch, in Fort Davis, Texas, May 11–18, 1996. Hot daytime temperatures and dry conditions kept the nights relatively warm but comfortable.

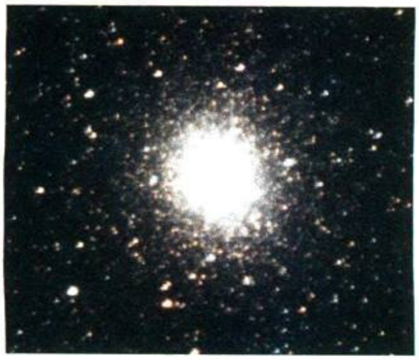
Several special events rocketed this year's TSP from the realm of ordinary into extraordinary.

The discovery of Earth-approaching asteroid 1996 JA1 was announced just prior to the TSP and was observed by many attendees. Brian Skiff of Lowell Observatory also announced that an asteroid he discovered, 4932, had officially been named Texstapa in honor of the TSP.

Alan Hale, codiscoverer of Comet Hale-Bopp, astonished his audience during his talk titled, "The Challenge of Comet Hale-Bopp," with the news that current calculations show Comet Swift-Tuttle on a possible collision course with Earth in the year 4479.

John Hudek of Galaxy Optics showed his "Baby Keck," a 25-inch f/3 scope that worked exquisitely without coma correctors or other optical wizardry. San Antonio's Adrian New demonstrated an ST-7 CCD camera attached to his 12-inch Meade LX200 Using TheSky software, he imaged for hours from a computer.

In addition to the nightly observing marathons through the 200 telescopes present, evening talks included CCD imaging techniques (Dennis di Cicco), and ranged from sunspots and starspots (Brian Skiff) to black holes and X-ray binaries (Craig Wheeler). Well-attended daytime presentations included, "Building of the Central Texas Observatory" (Kelley Knight, Austin, Texas), "How to Configure Your Home Video Camera and PC as a Fireball Motion Detector" (Franklin Miller, Aurora, Colorado), "Internet Astrophotography" (Robert Reeves, San Antonio, Texas), and "Observing Globular Clusters" (Barbara Wilson, Houston, Texas).



Adrian New

Belle of the Ball Omega Centauri sparkles in the west Texas skies above the Prude Ranch during this year's TSP. (8-inch f/1.5 Schmidt Astro camera, unhypered Fuji Super G 400 Plus film, 5-minute exposure taken May 15, 1996 at TSP.)

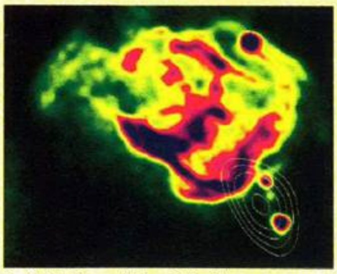
EVENT HORIZON

Looooong Distance Phone Call

The 305-meter Arecibo Telescope in Puerto Rico, the world's largest radio telescope, has been given a much-needed overhaul. A new system was installed on the 33-year-old telescope to better focus radio waves, which will enable astronomers to make observations of faint radio sources 10 times faster than before. A new one megawatt transmitter will improve radar studies of solar system objects by a factor of 20. Arecibo could now listen in on cellular phone calls on Venus and detect golf balls at the Moon's distance.

Cosmic Vinegar

A team led by University of Illinois astronomer David Mehringer has discovered the molecules of everyone's least-favorite salad dressing, vinegar, in an interstellar cloud 25,000 light-years from Earth. The team discovered the spectroscopic signature of vinegar with an array of nine 6-meter radio telescopes. Astronomers were interested in finding vinegar, (acetic acid, CH_3COOH), because it means that complex, biologically important molecules can form in deep space.



David Mehringer (Univ. of Illinois)

The contour lines show the location of vinegar in a gas-rich cloud 25,000 light-years away.

A Piece of Jupiter on Earth

Lawrence Livermore National Laboratory scientists have recently synthesized liquid metallic hydrogen, the most abundant substance in the solar system, not counting the Sun. Liquid metallic hydrogen is the stuff deep in Jupiter's interior that's responsible for the planet's stupendous magnetic field. Hydrogen is normally a gas, but on Jupiter, the overlying atmosphere squeezes it into a 40,000-km-thick layer of liquid, where it behaves like a metal. The scientists created the substance by trapping hydrogen in a cell and using shock waves to compress it to a pressure of 1.4 million atmospheres.

Telescopes 1, Squirrels 0

Legislation passed by the United States Congress in April has cleared the way for the University of Arizona to complete work on the Large Binocular Telescope on Mt. Graham. Environmental sympathizers had previously stalled the project with lawsuits claiming that the observatory would endanger the Mt. Graham red squirrel (see "The Saga of Mt. Graham," July 1995). While the observatory covers only 8.6 acres of land, a forest fire in late April burned 6,300 acres on the mountain.

CELESTAR 8 *by* Celestron®

THE LOWEST PRICE EVER ON AN 8" CELESTRON FORK-MOUNTED SCHMIDT-CASSEGRAIN TELESCOPE

- An economical but full featured 8" Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8 to offer the lowest price **ever** on a **Celestron** fork mounted 8" with so many features.
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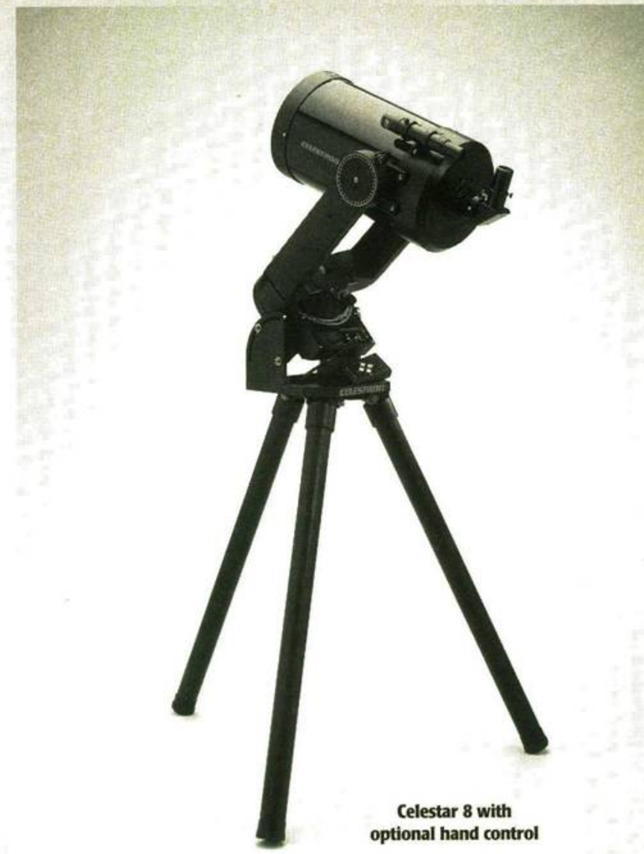
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the *Sky & Telescope* review – "the digital electronics of the C5⁺ delivered a near-perfect sidereal tracking rate."
- The Celestar 8 is powered by a single 9-volt alkaline battery and runs for 50 hours! The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0 to 90°.
- The new and unique Wedgpod is a combination tripod and wedge. It has a fixed height (33") and is lightweight without compromising its stability.
- **Made in the U.S.A.**
- Standard accessories included are: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).



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The **Celestar 8 Computerized** telescope is the same as the Celestar 8 but with the addition of a factory **installed** and **tested** Advanced Astro Master®.

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Contains an RS-232 serial interface to enable usage from PC programs.

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C5 - the ultimate in portability in a Schmidt-Cassegrain. 5" f/10 hand figured, diffraction limited optics with Starbright® coatings. Spoken highly of in reviews by *Astronomy* and *Sky & Telescope*. The C5 is an AC model. The **C5⁺** is a DC model for astronomy on the go and it runs off a single 9-volt alkaline battery. The C5⁺ also comes with a built-in drive controller. Included standard are the equatorial wedge, 5 x 24 Finderscope, Star Diagonal – 1¼ and a 25mm SMA eyepiece - 1¼".

ULTIMA® 9¼ – 2350mm f/10 with Starbright® coatings. A new, large aperture size utilizing the renowned Ultima PEC drive – totally cordless DC servo quartz drive system with PEC and powered by a single 9-volt alkaline battery. A unique focusing micrometer for ultra precise focusing for CCD imaging or astrophotography is included. Standard accessories are wedge, tripod, 6x30 Finderscope, hand control, 25mm SMA eyepiece – 1¼".

ULTIMA® 11 – 2800mm f/10 with Starbright® coatings. The largest Ultima (11") has been redesigned with more rigid sand castings for additional stability. Utilizes the same drive base as the Ultima 9¼ of which *Sky & Telescope* said, "Ultima's drive error was the least I have ever seen in a mass-market telescope". Standard accessories include a wedge, tripod, 7x50 Finderscope, hand control, 26mm Plössl eyepiece – 1¼".

CELESTRON®

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

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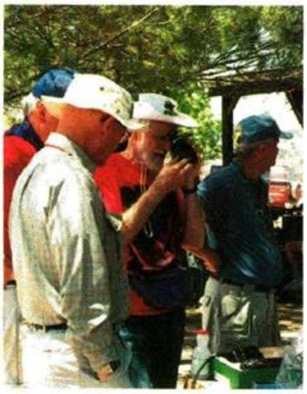
While not attending talks, TSPers visited McDonald Observatory. A swap meet and group photo session highlighted Friday's daytime activities and an astrophoto contest occupied many in the evening.

The wide variety of programs and activities gave some 650 participants many opportunities for relaxation and enjoyment, and the organizers of the 18th Annual Texas Star Party will now get a well-deserved break. Until next year, at least, when amateur astronomers will once again gather under the shadow-casting Milky Way of Texas skies.


ASTRONOMY: Patti A. Kurtz

Well known telescope designer John Gregory (center), enjoys the displayed equipment during the TSP swap meet Friday afternoon.

ASTRONOMY: John Shibley

Riversiders braved a raging snowstorm to take in a Memorial weekend's worth of astronomical talks and equipment deals. Saturday's snowflakes later yielded to crisp, clear-sky views of the Sun, Moon, and Comet Hale-Bopp.

Snow Yields to Stars at RTMC

As it has for 28 straight years, the Riverside Telescope Maker's Conference attracted 1,500-plus astronomy enthusiasts to Camp Oakes, a 4-H camp just outside the Southern California mountain town of Big Bear Lake. The Memorial Day weekend meeting attracted another, if somewhat uninvited, guest: an accumulation of snow.

But the late-spring dusting, something not unheard of for the San Bernardino Mountains, didn't dampen spirits. After deploying tarpaulins over telescopes, folks huddled under vendor awnings to look for deals or just moved indoors to hear talks.

Speakers like Alan Hale and Thomas Bopp, codiscoverers of Comet Hale-Bopp, related stories of serendipitous discovery. California supernova hunter Wayne Johnson told of an extragalactic supernova he discovered barely two weeks before the conference. And dozens of astrophotographers, both seasoned and beginner, shared picture after splashy picture of subtle detail in Comet Hyakutake.

Come Saturday afternoon, though, the snow stopped and the Sun came out, letting amateur telescope makers show off their latest creations. Dick Schwab of San Diego placed two mirrors in a Dobsonian to create an intriguing binocular scope. An observer looks through the twin oculars of a pair of binoculars that's had its front lenses removed. Another ATM, Dave Pitou of Boise, Idaho, showed a scope he's fitted with a tiltable secondary mirror. The secondary shifts position to direct light from a 20-inch f/4 main mirror into one of two eyepieces mounted in a dual-ocular focuser. Pitou made the scope's tube out of a lightweight, honeycombed composite of Kevlar and fiberglass.

Clearing skies also let observers enjoy a waxing gibbous Moon, numerous deep-sky objects and, after moonset, a brightening Comet Hale-Bopp. Younger, eagle-eyed skywatchers even spotted with the unaided eye the magnitude-7.1 glow in Sagittarius.

Next year's conference will be held May 24-26, over Memorial Day weekend. For more information call (909) 948-2205.

Mark Coco: 1960-1996

Astronomy author and popularizer Mark Coco died May 21 after a lengthy illness. He was 36.

Coco was a member of the Southern California astronomical community for almost a quarter of a century, writing for ASTRONOMY, and enjoying all aspects of his hobby with fellow amateurs through conferences and star parties. In the 1980s, he also served as Celestron's manager of consumer relations.

Friend and fellow author Stephen Edberg recalls Coco's passion for astrophotography. "Mark and I spent many nights observing and photographing together at many sites around Southern California," says Edberg. "He took one of the finest pictures of the zodiacal light and band that I've ever seen."

The Coco family is taking donations for a fund set up to promote worthy causes throughout Southern California. Send contributions to the Mark Coco Fund, c/o St. Andrews Presbyterian Church 301 Avenue D, Redondo Beach, CA 90277.

ASTRONOMY: David J. Eicher

Mark Coco at 1993's Universe astronomy conference.

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"Affordable, easy-to-use telescopes with sharp optics and sturdy mounts." Astronomy *(12/93)*

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Now with FREE 5x Finder Scope!

6" f/8	#9901 ***$319*** (39.00)
8" f/6	#9902 ***$419*** (49.00)
10" f/4.5	#9905 ***$599*** (69.00)

10", 12.5", & 16" Premium Deep Space Explorers

Advanced large-aperture deluxe model featuring Pyrex mirrors and enhanced aluminum optical coatings with 94% reflectivity for brightest images. Also formica/teflon bearings for buttery smooth movements, and oversized 4-vane fully adjustable secondary mirror support. Unique optical tube handles allow easy lifting of telescope tube.

Comes with high-quality 26mm Plössl eyepiece and now with your choice of focuser!

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10"	#9913 ***$749***	#9922 ***$759***	#9919 ***$808***	#9916 ***$838***	(69.00)
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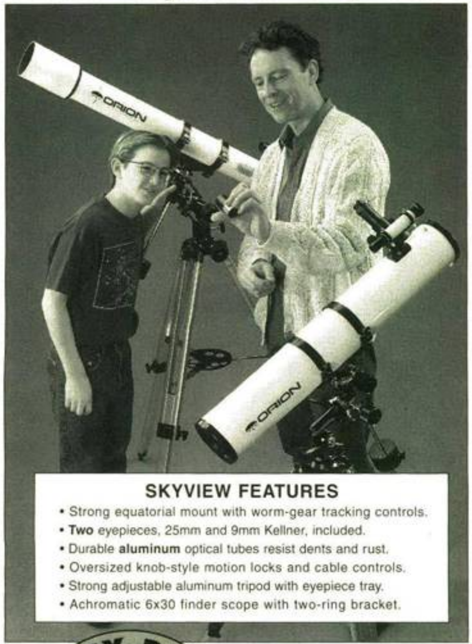

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- Strong equatorial mount with worm-gear tracking controls.
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- Durable **aluminum** optical tubes resist dents and rust.
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SkyView™ 90mm Refractor

This fantastic large-aperture refractor telescope features a multi-coated f/11 achromatic objective lens for superb images. Especially suited to planetary, lunar, and stellar observation, its aperture is large enough to give spectacular views of star clusters and nebulas. Smooth rack-and-pinion 1.25" focuser, 90° prism diagonal, and **two** Kellner eyepieces, 25mm (40x) and 9mm (111x).

#9072 ***$599*** (28.30)

SkyView™ 4.5" Reflector

This all-new reflector is ideal for the beginning astronomer who wants the features of an equatorial mount, without compromising stability. The 114mm-diameter (4.5") precision optics are great for deep-space and planetary observation. Includes smooth rack-and-pinion 1.25" focuser and **two** Kellner eyepieces, 25mm (36x) and 9mm (100x). f/8 focal ratio.

#9071 ***$399*** (26.58)

Electric Focuser for SkyViews

Enjoy smooth, jiggle-free focusing of your Orion SkyView 90mm Refractor or SkyView 4.5" Reflector, without touching the scope itself. Attaches quickly over focus knob. Compact two-directional hand controller. Clutch disengage button allows manual focusing at any time with motor in place. Runs on two AA batteries (not included). Motor also fits many Celestron scopes, including Premium 80, C4.5, and GP-C102.

#2363 **$39.95** (3.19)

ShortTube™ 80mm Refractor

Here's a compact 400mm f/5 scope that's great for both daytime nature viewing and casual stargazing. Features a fully coated 80mm objective lens, rack-and-pinion focuser, 45° erect-image diagonal, TWO 1.25" Kellner eyepieces—25mm (16x) and 10mm (40x), and a 6x30 finder scope with long-stem bracket. Telescope attaches quickly to any photo-type tripod. Highly portable—take it anywhere!

New!

#9086 **$249** (9.22)

Observer 60mm Refractor

Great for viewing Saturn's rings, lunar craters, and distant earthly scenes. Features an all-metal optical tube and altazimuth mount, precision prism-type diagonal and coated 25mm (28x) Kellner eyepiece, and hardwood tripod. Compare with models selling for much more! Standard model has 90° diagonal prism for stargazing; Terrestrial model includes 45° correct-image diagonal better suited for ground observation.

Standard Model
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Terrestrial Model
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Great performance at Orion's low direct-discount price. Internally blackened, threaded for filters (except 40mm .965").

.965" Kellner and Achromatic Huygenian
K 18mm #8584, K 25mm #8585, AH 40mm #8586
$39.95 **each** (2.98)

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$49.95 **each** (2.98)

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Fantastic Fully Coated Eyepieces at an Incredibly Low Price!

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7.5mm #8738, 10mm #8736, 12.5mm #8726, 17mm #8734, 20mm #8733, 26mm #8732	**$49.95** **each**	(3.45)
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Custom Field Case *(holds up to four eyepieces except for the 32 mm or 40mm)*	#5911 **$12.95**	(2.19)

Illuminated Reticle Eyepieces

Great for astrophoto guiding, polar alignment, and other uses. All models illuminated with a night-vision red LED.

12mm Kellner 1.25"
Double crossline reticle, fixed brightness. Plugs into power panel drive bases.
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With fully adjustable brightness control. Double crossline reticle. Batteries included.
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Bull's-eye within crosshairs, adjustable brightness. Needs two SR-44 batteries, not included.
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About half the length of our regular barlows for added convenience. Magnifies 2x or 3x when positioned behind or in front of diagonal, respectively, on a refractor or Schmidt-Cassegrain. Works in all scopes, including those in which longer barlows won't work.

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Rated the #1 broadband filter by *Sky & Telescope* (7/95): " I Found the Orion SkyGlow to be the most useful."

For slightly to moderately light-polluted areas.

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SC Broadband Filter fits rear cell of Meade and Celestron Schmidt-Cassegrain scopes.
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"The UltraBlock gave superior results."
***Astronomy* (2/91)**

For severely light-polluted areas and faint nebulas.

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SC UltraBlock Filter fits rear cell of Meade and Celestron Schmidt-Cassegrain scopes.
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Moon Filters

Cuts 87% of the light from the Moon, reducing glare to reveal more detail and help preserve night vision.

.965" #5664, **1.25"** #5662
$15.95 (2.43)

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Full-aperture optical glass filters, for superb images and safe viewing of the Sun. Great for both visual and photographic use. Fits over front of telescope.

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.965" Set of 4 #80A Blue, #58 Green, #25 Red, #15 Yellow. #5510

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2" Set of 4 Includes #80A Blue, #58 Green, #21 Orange, and #12 Yellow.
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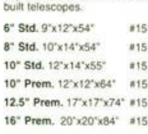
With patented unbreakable latches, die-cut foam inserts. (Inside dimensions shown)



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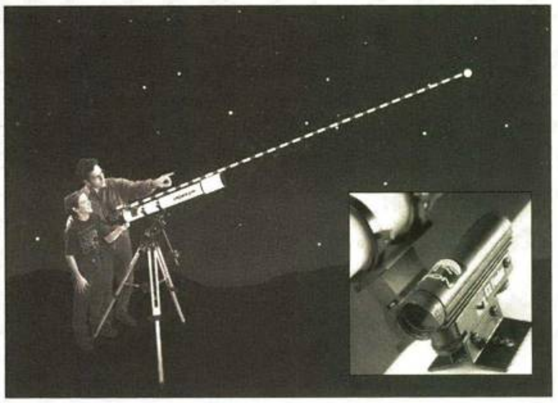

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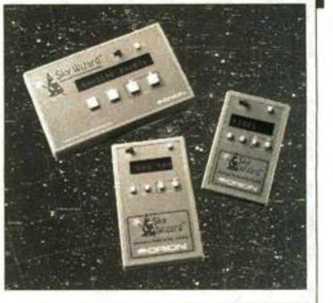

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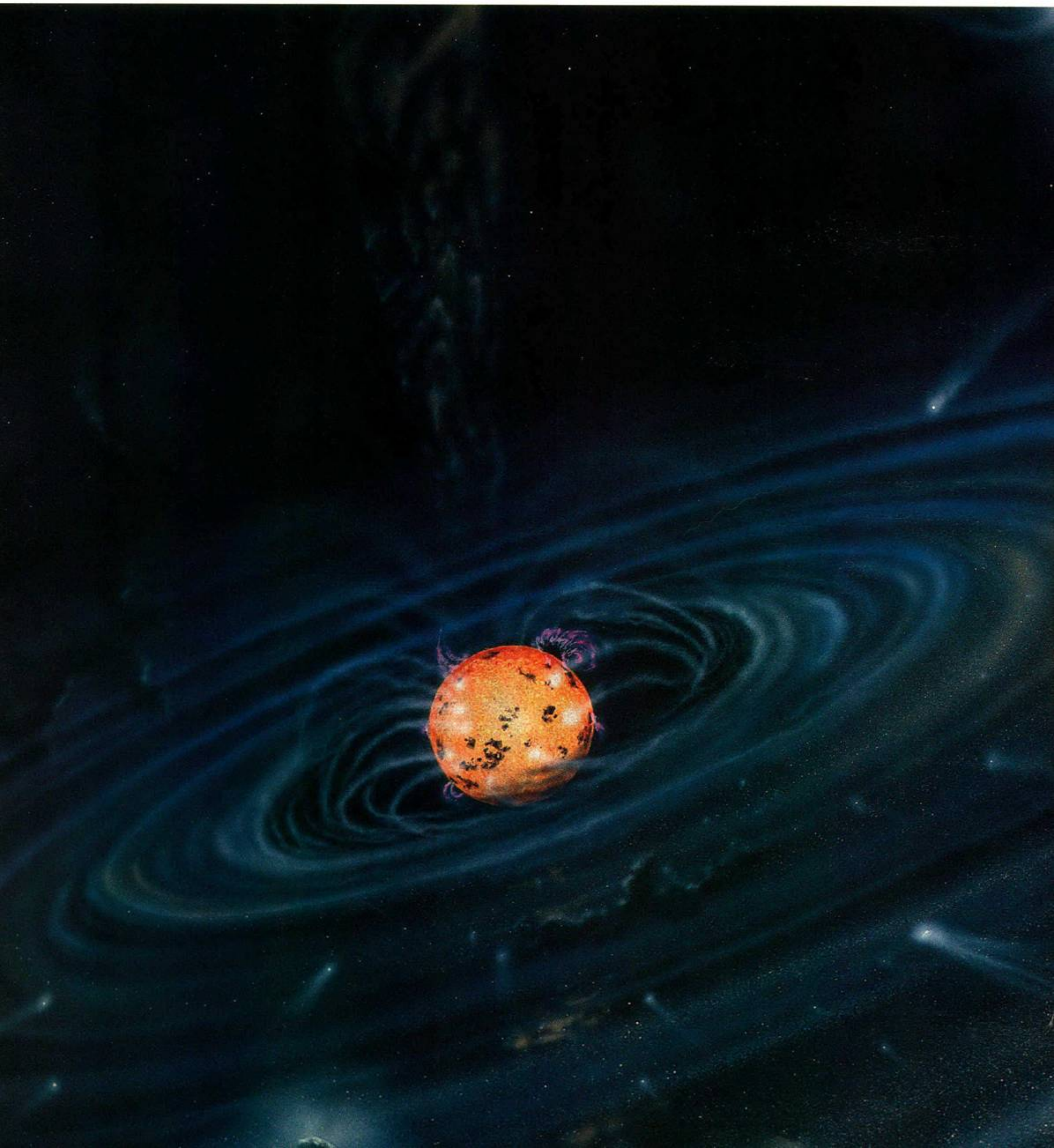

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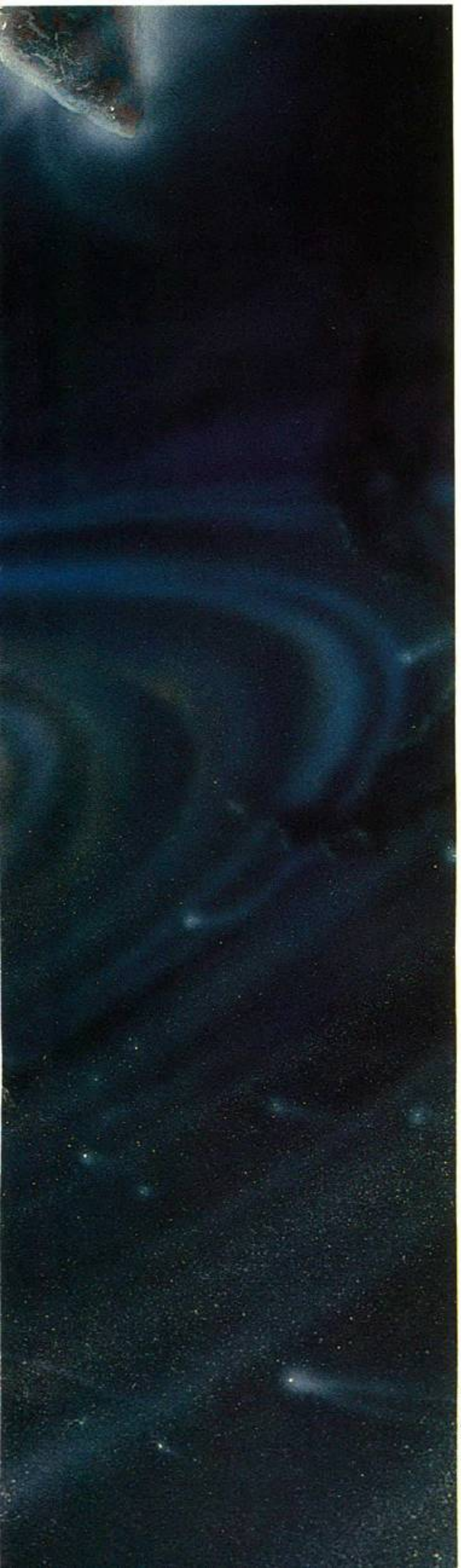


Michael Carroll

Wild and crazy T Tauri stars are testing astronomers' stellar evolution theories.

by Sally Stephens

We all go a bit wild in our youth, and stars are no exception.

The rebellious teenagers of the stellar world are the T Tauri stars (the archetype can be found in Taurus the Bull). T Tauri stars are young, hyperactive; bright one day and dim the next. They're a mass of contradictions, and they're trying astronomers' patience as well as their best theories.

Making sense of them is a challenge. But astronomers eagerly accept that challenge because our Sun was probably once a T Tauri star. Knowing what happens during this awkward time in a star's life will help us better understand how our Sun, planets and, ultimately, we got here.

For years, the only thing astronomers knew about these enigmatic stars was that they were young, no more than ten million years. Most T Tauri stars, in fact, are still physically near the dark molecular clouds from which they were born.

"The T Tauri phase is the first phase of star formation in which the star is visible," notes Gibor Basri, an astronomer with the University of California at Berkeley who has worked extensively on T Tauri stars. "Prior to that, you can't see it because it's enveloped in this placental cloud."

Early in their lives, T Tauri stars shine from the gravitational energy stored during their initial contraction and from deuterium burning in their cores. Their surfaces seethe with violent activity, indicating of a magnetic field well over a thousand times more powerful than the Sun. Huge, dark "starspots" cover 10 to 15 percent of their surface, and enormous flares explode into space. "If you could look through a telescope at a T Tauri star as close to us as our own Sun," says Suzan Edwards, an astronomer at Smith College and a member of the Five College Astronomy Department, "it would knock your socks off."

We can't actually see the surface of T Tauri stars; even the nearest ones are too far away. But astronomers do see jets of material moving at high speeds away from them. Such jets are typical of young protostars, including those still embedded within their birth clouds. Thin disks of gas and dust that stretch a distance roughly the size of our own solar system surround many T Tauri stars. This isn't too surprising, however, since astronomers think such disks form naturally during the initial gravitational collapse that leads to the birth of a star. But it's also apparent that material from the disk is falling onto the star while other material is streaming away from it.

Not Just Any Old Disk

Astronomers suspect that the solar-system-sized disks around T Tauri stars are more than just left-behind debris. They play an active role in many of the unique properties associated with the young stars, largely because the disk material is drawn inexorably toward the star. "If you could go and look at a hydrogen atom or a little dust grain and watch it for a number of years," Edwards explains, "you would see that it's slowly spiraling in toward the central star."

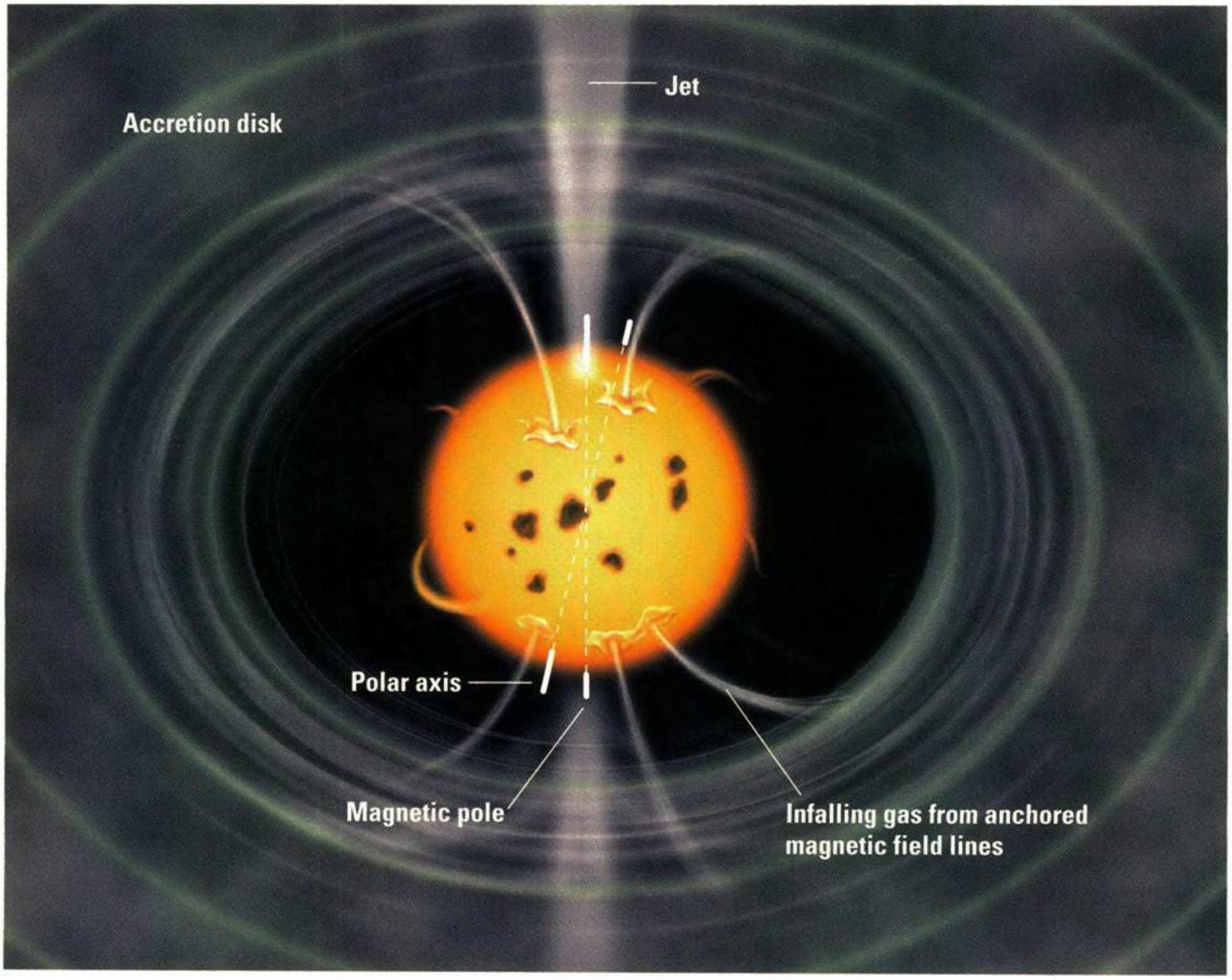
This accretion process deposits about one ten-millionth the mass of the Sun onto the surface of a T Tauri each year — rather small compared to earlier stages in the star's life when the accretion rate is much higher. "Most of the growth of the star has already been accomplished by the time we see it as a T Tauri star," she adds. Nevertheless, the central star will grow by about one-tenth the mass of the Sun during the million or so years disk accretion takes place.

As gas from the disk spirals in, it accelerates. But the star's surface rotates more slowly than the material orbiting around it (tens of kilometers per second for the former; hundreds of kilometers per second for the latter). So, when the two meet at the star's equator, the disk gas is forced to slow down rather abruptly, creating an area of very hot gas, with temperatures reaching 11,000 kelvins. This hot region radiates strongly in the ultraviolet, producing T Tauri stars' characteristic ultraviolet excess and emission lines. The disk is also responsible for an observed infrared excess, as dust within it absorbs energy from the central star and reradiates it at infrared wavelengths.

Accretion further explains the extreme variability observed both in the overall brightness of T Tauri stars and in their spectra. Observations of the same star made from night to night — and sometimes just hours apart — can show dramatic changes in the spectral lines. "There seem to be noticeable fluctuations in the amount of material that is landing on the surface of a particular star," Edwards says, adding that it's not clear exactly what happens; only that something in the accretion process changes. Maybe the disk is lumpy, and material falls onto the star in chunks. Or perhaps the star's magnetic field isn't constant across the stellar surface or in its interactions with the disk.

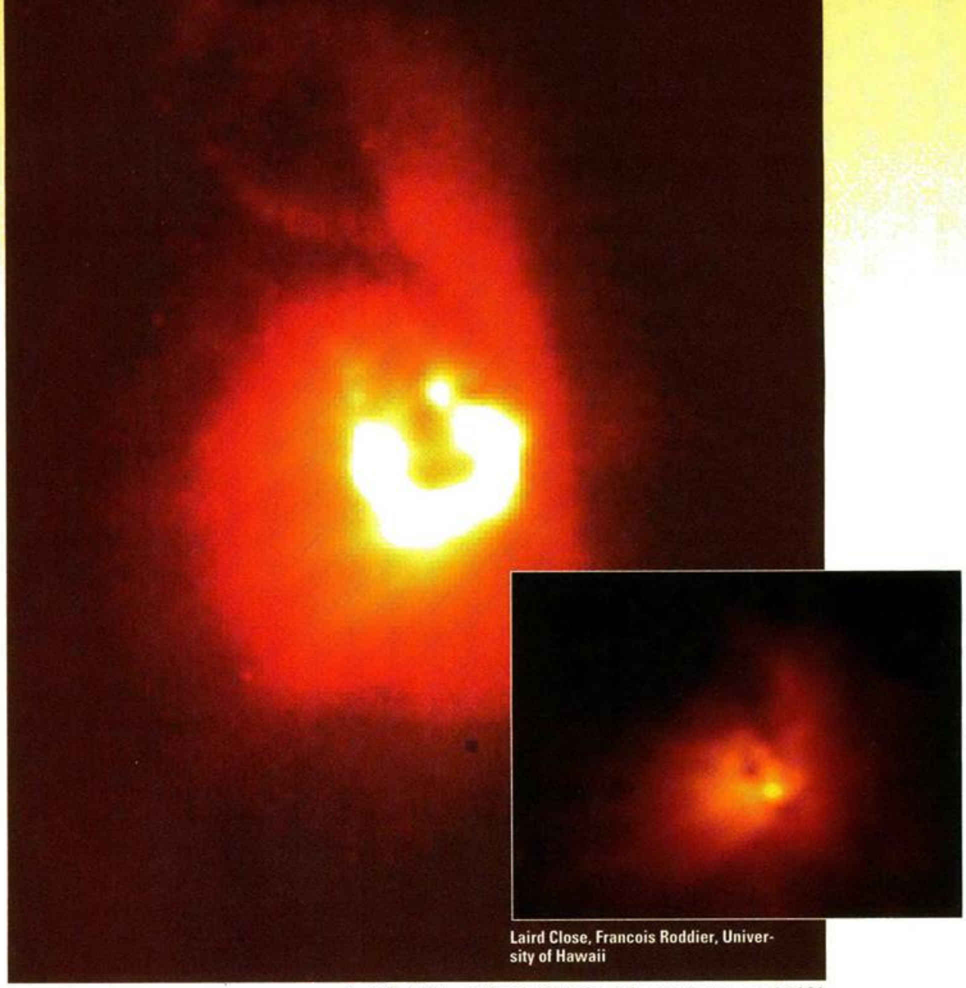
Magnetic Possibilities

Astronomers have only recently come to appreciate the critical role magnetic fields play in a T Tauri star's life. Stars generate these fields when hot gas moves, both due to internal convection and stellar rotation. Because T Tauri stars rotate much faster than adult stars like the Sun — spinning once every few days versus the Sun's month-long rotation period —


Jet
Accretion disk
Polar axis
Magnetic pole
Infalling gas from anchored magnetic field lines

ASTRONOMY: Elisabeth Rowan

T Tauri stars may draw gas from their surrounding accretion disk along "anchored" magnetic field lines. The lines pass through the disk at a location that orbits as fast as the star spins. Gas rushes up these field lines and falls onto the star's surface, creating a hot spot.



Laird Close, Francois Roddier, University of Hawaii

David A. Weintraub (Vanderbilt University) and colleagues, and NASA

The C-shaped dust feature of HL Tauri, revealed in this recent HST image, may harbor a star. Inset: Near-infrared image showing a cavity cleared by HL's strong bipolar jet.

their magnetic fields should be thousands of times stronger.

It's not hard to imagine how the strong magnetic forces generated within T Tauri stars impact the disk, especially those parts that are closest to the star. Indeed, many astronomers now think that instead of a disk that touches the star, there may be a gap — several times as large as the star's radius — between the stellar surface and the inner edge of the disk. "A strong field would have enough magnetic pressure to disrupt the innermost regions of the disk," Edwards says, "preventing the disk from reaching the stellar surface."

At first glance, it seems that such a gap would prevent material from accreting onto the star. But research by Berkeley astronomer Frank Shu and his colleagues has shown how this can be overcome.

A star's magnetic field resembles a bar magnet, complete with curved lines of magnetic force connecting the two poles. These lines are called field lines. At some radius in the disk, material orbits the star at the same rate that the star spins. The star's magnetic field can "grab" onto the gas and dust in the disk at that point without feeling any forces twisting it.

Material moving through the disk can then "anchor" itself to this part of the magnetic field. "[Disk material] finds the magnetic field lines of the star," Edwards explains, "and follows them up and over and smashes into the stellar surface." Basri calls this process "magnetospheric accretion."

As the material moves along the field lines, it is accelerated by the magnetic field. Material spiraling in through a disk that merged with the star's equator wouldn't move as fast since most of its motion would be in the direction of its orbit. "What we see are very large infalling velocities directed toward the star," Edwards says, "as expected for acceleration guided by a magnetosphere."

In addition, Basri and his colleagues have identified features in the spectra of several T Tauri stars that may be caused by "hot spots" on the stellar surfaces. The features vary with periods of a few days, the same as the stars' rotation periods. Basri thinks they may be seeing the places where disk material, streaming along the stellar magnetic field lines, is smashing onto the star's surface.

Not all T Tauri stars show regular changes in their spectral lines; their variations follow no particular pattern. "That makes me worry," Basri laughs. "We may not have the whole picture right." Critics argue that magnetic fields contained within the disk and unrelated to the central star are involved. Or that there is no gap in the disk near the star. Nevertheless, Edwards notes, "There are some pieces of the T Tauri puzzle, especially the very high-speed infalling material, that are very hard to explain otherwise."

Blowing in the Wind

Accretion also influences the rate of outflow of material from T Tauri stars. This outflow is typically about 10^{-7} times the Sun's mass each year. With their high speeds and relatively large amounts of ejected gas, T Tauri winds have energies that correspond to about one-hundredth the total luminosity of the star. "There's really no way to produce that level of mass outflow from the star itself," Basri adds. Something else must be driving the wind. Evidence suggests it's accretion.

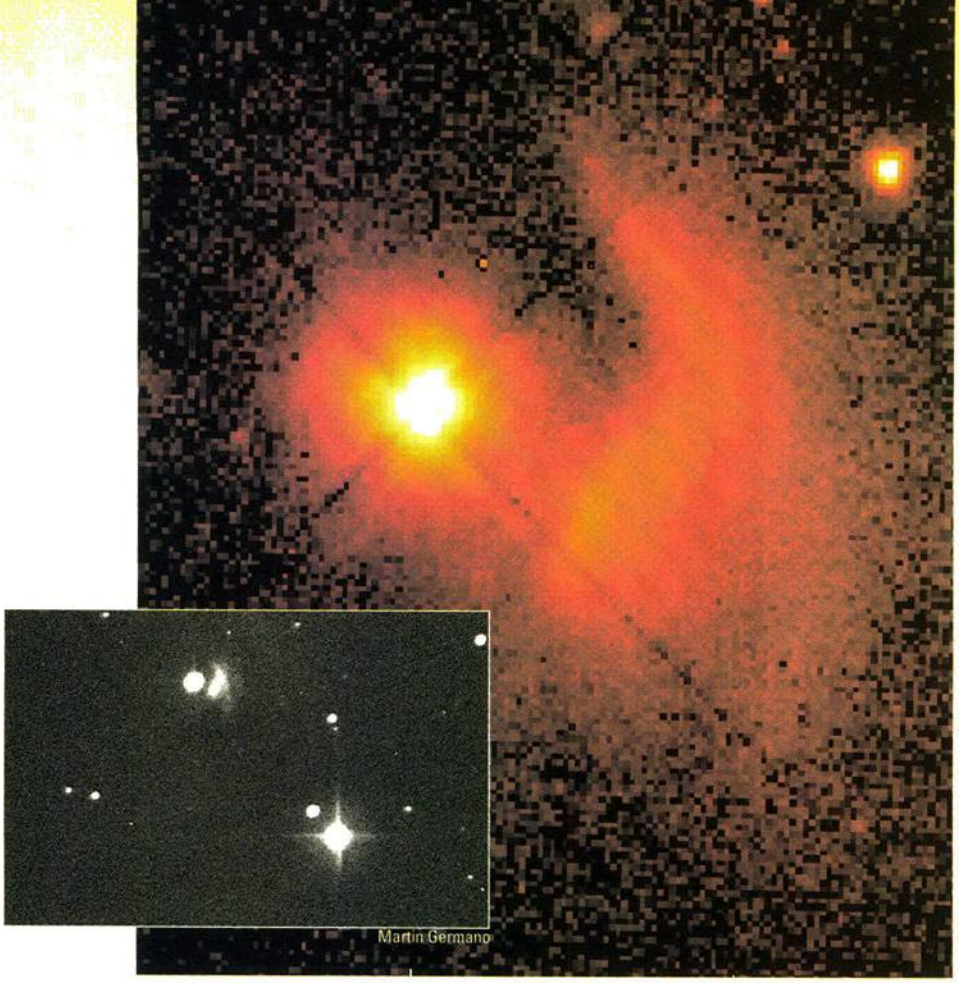
Astronomers don't see energetic outflows around "weak T Tauri stars," so named because of their relatively weak emission lines. More important, weak T Tauri stars don't have inner accretion disks. Measurements indicate the rate of outflow is proportional to the rate of accretion. Magnetic fields are most likely responsible for redirecting some of the infalling material and sending it away from the star. In the magnetospheric accretion model, this outflow follows naturally from the way material farther out in the disk pushes the star's unanchored magnetic field lines toward the star. The lines pile up near the point at which the field is anchored to the disk. Unable to move any closer, their connection with the star ultimately breaks. Gas snagged by these broken outward-pointing magnetic field lines is propelled away from the star.

This notion is still controversial, however. Some astronomers argue that the magnetic fields responsible for redirecting infalling material come from the disk itself, not from the T Tauri star. The advantage magnetospheric accretion holds is that it's simple. "The same model that successfully explains magnetospheric accretion also nicely accounts for an outflow mechanism," Basri notes.

Slowing Down the Star

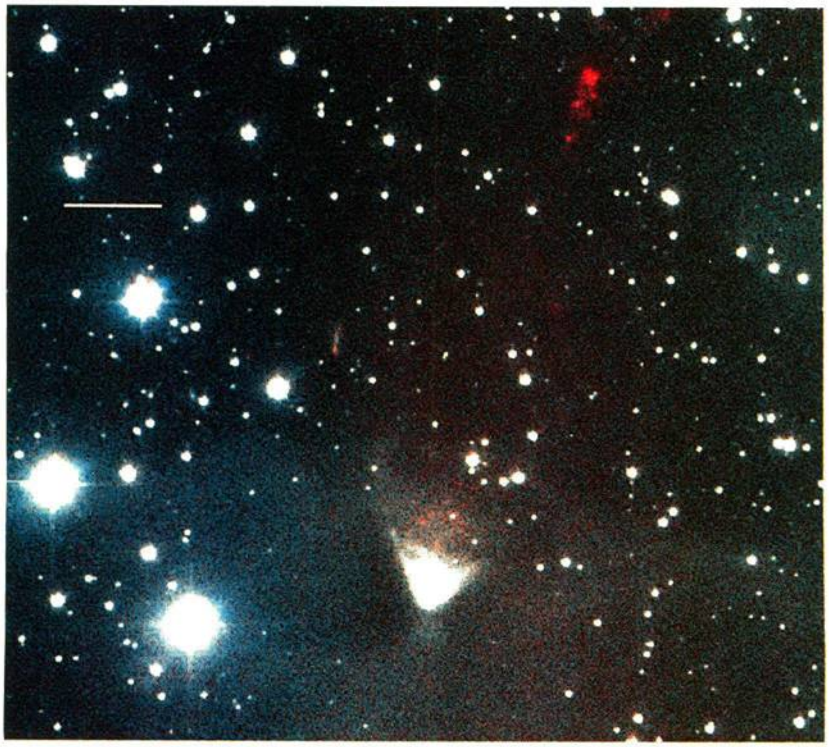
The interaction between the star's magnetic field and the disk also regulates how fast the star rotates. T Tauri stars are still contracting from their birth cloud. At the same time, they're adding mass as material from the disk falls onto them. Both contraction and matter accumulation would normally cause them to spin faster. But, though they spin much faster than the Sun, they don't spin as fast as astronomers would expect, given the amount of shrinkage and weight gain. Astronomers think that when the magnetic field attaches to the disk, it acts as a brake that keeps the star from spinning any faster. How this might work can be seen in weak T Tauri stars. With no disk for the magnetic field to grab, the rotation rates of weak T Tauri stars are indeed faster than those of their classical counterparts.

Magnetic braking may answer one of the most puzzling aspects of how our solar system formed—the angular momentum problem. Angular momentum is a measure of the tendency of a rotating body to keep spinning. It depends on the body's rotation speed, mass, and size. When we look at the solar system today, nearly all its angular momentum is carried in the planets, the remnants of the disk. Theories of how the solar system formed must explain how the Sun came to have so little


Martin Germano

Joel Kastner and David A. Weintraub (Haystack Observatory and Vanderbilt University) STScI.

A near-infrared image of the circumstellar nebula surrounding T Tauri. Hind's Variable Nebula, the arc-like feature, is illuminated by T Tauri and its, presumably younger, companion. Inset: A visible-light photo of T Tauri.


Mercedes Gomez, Scott Kenyon, Barbara Whitney (Harvard-Smithsonian Center for Astrophysics)

Emission nebulae are often seen along jets near T Tauri stars. The one at upper right (red patch) lies 7 arcminutes from PV Cephei, the cone-shaped object at lower center.

angular momentum and rotate as slowly as it does.

Material falling onto the star during the T Tauri phase carries the high angular momentum of the disk along with it. And yet it doesn't transfer any to the star. Where does it go? Most is probably carried away with the gas streaming outward. "You get these powerful jets coming out because the star is shedding or dumping angular momentum," Basri says. "It's not accepting it. It's throwing it away." This provides further evidence of the intimate link between the disk, magnetic fields, and outflow in T Tauri stars.

Eventually, the accretion stops, although astronomers aren't sure exactly why. It may be that the powerful T Tauri winds blow away any gas and dust remaining around the star that's not already in the disk. With nothing to replace material lost to the star, the disk essentially "drains" away. Or it may be that accretion stops when planets begin to form. Gaps may be created in the disk where material has gathered together into a protoplanet. Such gaps would halt any general flow of disk material toward the star.

However it happens, once accretion stops, the link between the star and the disk breaks. For a short time, the star spins a little faster as it continues to shrink in size. But a gentle wind of charged particles leaving the star's outer layers in all directions, analogous to the solar wind, combined with a strong magnetic field, causes the star to lose angular momentum as wind particles carry some of it away from the T Tauri. Since the star can't get any angular momentum from infalling material to compensate for that which is lost, the star begins to slow its rotation.

The strength of the magnetic field, too, weakens, dependent as it is on the rotation rate. This, in turn, prevents a T Tauri from losing as much angular momentum. "That's the state the Sun is in," Basri explains. "It has a relatively weak field, is losing relatively little angular momentum, and it's rotating slowly for a star."

In our own solar system, the dust and gas in the disk eventually formed the planets. There are a few cases of weak T Tauri stars in which the inner portions of the disk appear to have been cleared out, although an outer disk remains. "We can only see the disk if it's made of very, very fine dust," Basri explains. Micron-sized dust grains radiate efficiently in the infrared; larger dust grains do not. In weak T Tauri stars, no micron-sized dust is seen in the inner disk. "Either they have coagulated into something bigger," he adds, "or they've been blown away somehow." It's tempting to say that the disks in these stars have taken their first steps toward forming planets. "These look like solar systems in formation," Basri cautions. "but we don't know if there are planets there."

Although details remain to be worked out, the basic picture of an accretion disk around a magnetically energetic star seems to explain the emission, infall, outflow, variability, and slow rotation of T Tauri stars. "It's sort of a nice neat package," Edwards adds. "You have a disk, a star, a stellar magnetic field, and the whole system is explained." □

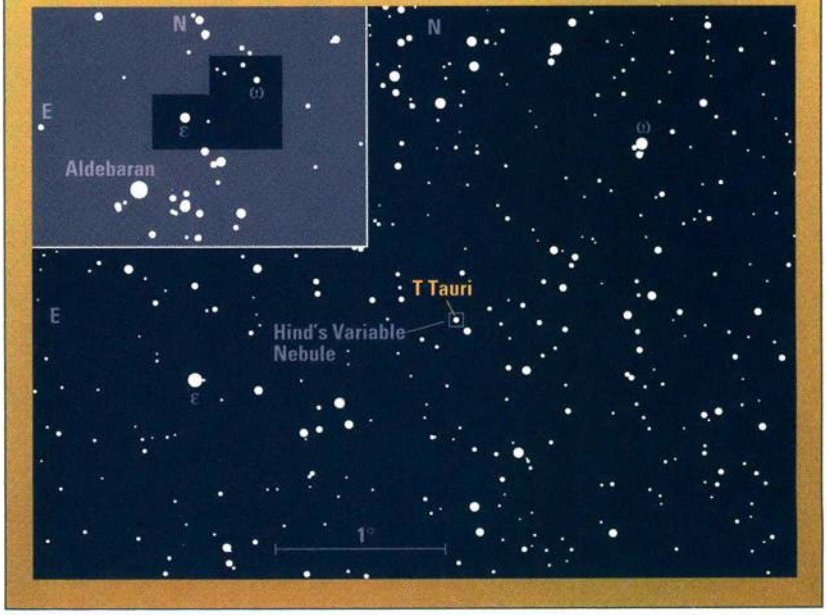
Sally Stephens is a science writer living in San Francisco. Her previous article for ASTRONOMY, *"Second Chance Planets," appeared in the January 1996 issue.*

Observer's Challenge:
Trailblaze to T Tauri

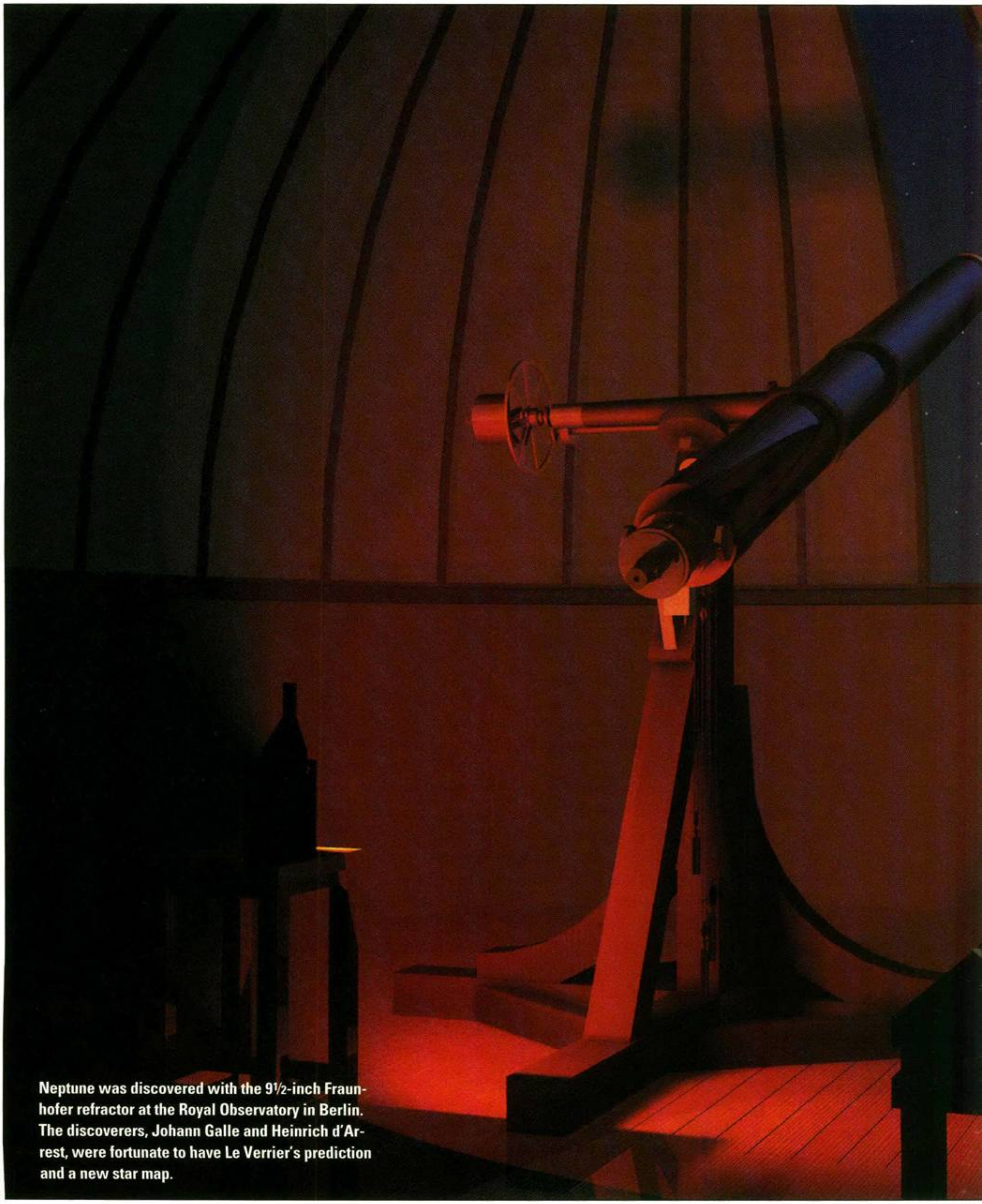
The horns of Taurus the Bull slash through the late-night autumn skies — a resplendent reminder that winter is not far behind. Northwest of the Bull's face lies the enigmatic star T Tauri, itself a reminder that we don't know everything about stars.

T Tauri varies erratically in brightness from about 9th to 13th magnitudes, although it rarely fades below magnitude 10.6. Just 45 arcseconds to its west is Hind's Variable Nebula (NGC 1554-1555). Over the last century, this nebula has faded from view and then brightened dramatically.

To find T Tauri and Hind's Variable Nebula, you will need at least a 10-inch telescope. Locate ε Tauri north of the Hyades (the V-shaped group that forms the face of the bull). Jump 1.8° west and a little north to T Tauri. With a good set of setting circles and a polar-aligned mount, you can locate T Tauri by centering your field of view 1 minute of right ascension west of δ^1 Tauri and slewing north in declination 2°. T Tauri is the northernmost star of a pair that should be near the center of your field.



Neptune's Discove



Neptune was discovered with the 9½-inch Fraunhofer refractor at the Royal Observatory in Berlin. The discoverers, Johann Galle and Heinrich d'Arrest, were fortunate to have Le Verrier's prediction and a new star map.

Julian Baum

ry 150 Years Later

British astronomers had Neptune in the bag. But then they let it slip away. . . .

by William Sheehan and Richard Baum

'Le Verrier's Planet Found," announced the London *Times* headline for Thursday, October 1, 1846. This was startling news to most people of the day, and 150 years later, it is still one of the most memorable events in astronomy. For the first time in the 19th century and only the second time in history, astronomers had discovered a new major planet in the solar system.

The name Johann Gottfried Galle, a German astronomer at the Royal Observatory in Berlin, will forever be etched in history for first recognizing the planet. But the lion's share of the glory goes to French mathematical astronomer Urbain Jean Joseph Le Verrier. It was Le Verrier's prediction of the planet's position among the stars that led Galle to his finding.

The discovery of the planet made a profound impression on astronomers of the day, who hailed it as the "Zenith of Newtonian mechanics." But to the lay mind, the discovery seemed nothing short of miraculous. One of Le Verrier's colleagues commented that he had "discovered a star with the tip of his pen, without any instruments other than the strength of his calculations alone."

Neptune's discovery seems almost inevitable in retrospect, but when Le Verrier first published his new planet prediction in June 1846, he found no one willing to look for it. Apparently a brief search was undertaken at the Paris Observatory, but it was soon abandoned, and Le Verrier knew nothing of searches that were going on at the time in England. At last, losing patience, he wrote a letter to Galle. The

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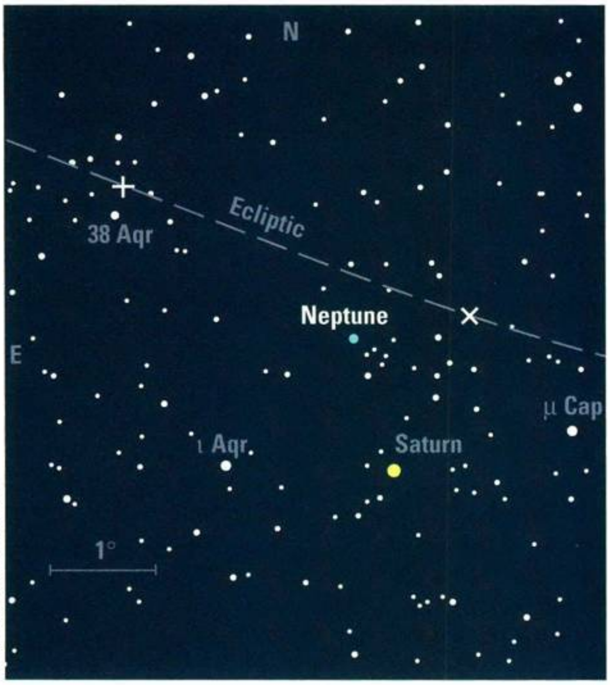
Johann Gottfried Galle

Mary Lea Shane Archives of the Lick Observatory

Urbain Jean Joseph Le Verrier



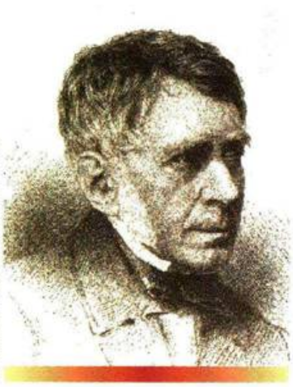
ASTRONOMY: Lee Vande Visse

When Galle discovered Neptune, the planet was less than 1 degree from Le Verrier's prediction (X) and less than 2 degrees from Adams' prediction (+).

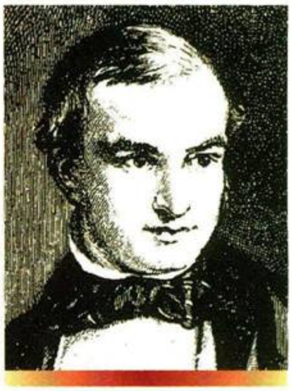
idea instantly seized Galle's imagination, and he sold it to his director, Johann Franz Encke, who remarked, "Let us oblige the gentleman in Paris."

On the night of September 23, 1846, just hours after Galle received Le Verrier's letter, Galle took his place in the observing chair of the Royal Observatory's 9½-inch Fraunhofer refractor. At first he attempted to find the planet by locating its small disk among the stars of Aquarius, as Le Verrier had suggested. A German student and volunteer observer, Heinrich d'Arrest, waited patiently as Galle's discouragement mounted. Finally, d'Arrest suggested that they try using a star chart. Rummaging through a drawer, they found a chart so fresh that it had not yet been mailed to observatories elsewhere. After about half an hour of searching, at just about midnight, Galle sighted an 8th-magnitude star that d'Arrest could not find on the map — it was only 55 arcminutes (about two Moon diameters) from Le Verrier's calculated position. D'Arrest immediately cried out, "That star is not on the map!" The following night, Galle noticed that the object had moved, proving that it was not a fixed star but rather an object orbiting the Sun.

"Monsieur," Galle wrote to Le Verrier on September 25, "the planet of which you indicated the position really exists." Le Verrier savored his moment of supreme triumph, and replied to Galle, "I thank you for the alacrity with which you applied my instructions. We are thereby, thanks to you, definitely in possession of a new world."


Astronomical Society of the Pacific

Sir George Biddell Airy


University of Chicago Library

John Couch Adams

Meanwhile, back in England, news of the planet caused more embarrassment than jubilation. While reading the *Times*, Sir John Herschel, one of England's leading astronomers, reacted in shocked disbelief. On September 10, just two weeks prior to Galle's discovery, he had remarked presciently to the British Association for the Advancement of Science: "We see it [the new planet] as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far-reaching line of our analysis with a certainty hardly inferior to that of ocular demonstration."

Herschel's uneasy state of mind was due to his knowledge that the planet's position had been first predicted not by the Frenchman Le Verrier, but by a young English mathematician, John Couch Adams, a recent graduate of Cambridge University.

Like Le Verrier, Adams had immersed himself in an analysis of Uranus' motion. Uranus had been wandering slightly off its predicted course ever since its discovery by Herschel's father, Sir William Herschel, in March 1781. In the early 1800s Uranus traveled too fast, as if it were being pulled forward by another body. But after 1822, it began to slow down, as if another body was holding it back. As we now know, Uranus and Neptune were in conjunction in 1821–22, meaning Uranus was overtaking its more distant cousin.

Mary Lea Shane Archives of the Lick Observatory

James Challis

Both Le Verrier and Adams diagnosed the problem as an unknown planet orbiting outside Uranus. By using the best available mathematical methods and painstaking hand-computation, they independently determined the unknown planet's position — and their results agreed to within half a degree. However, Adams reached his initial conclusion in September 1845, nine months before Le Verrier's first published prediction, and a full year before Galle had even sighted the mystery planet. Adams' theoretical position was within two degrees of where Neptune was lurking in Aquarius.

Unfortunately, Adams did not publish his results. He was a brilliant mathematician, but he was painfully shy and sensitive, and he failed to make a strong impression on his superiors. A fellow Cambridge student remembered him only as "a rather small man, who walked quickly, and wore a faded coat of dark green."

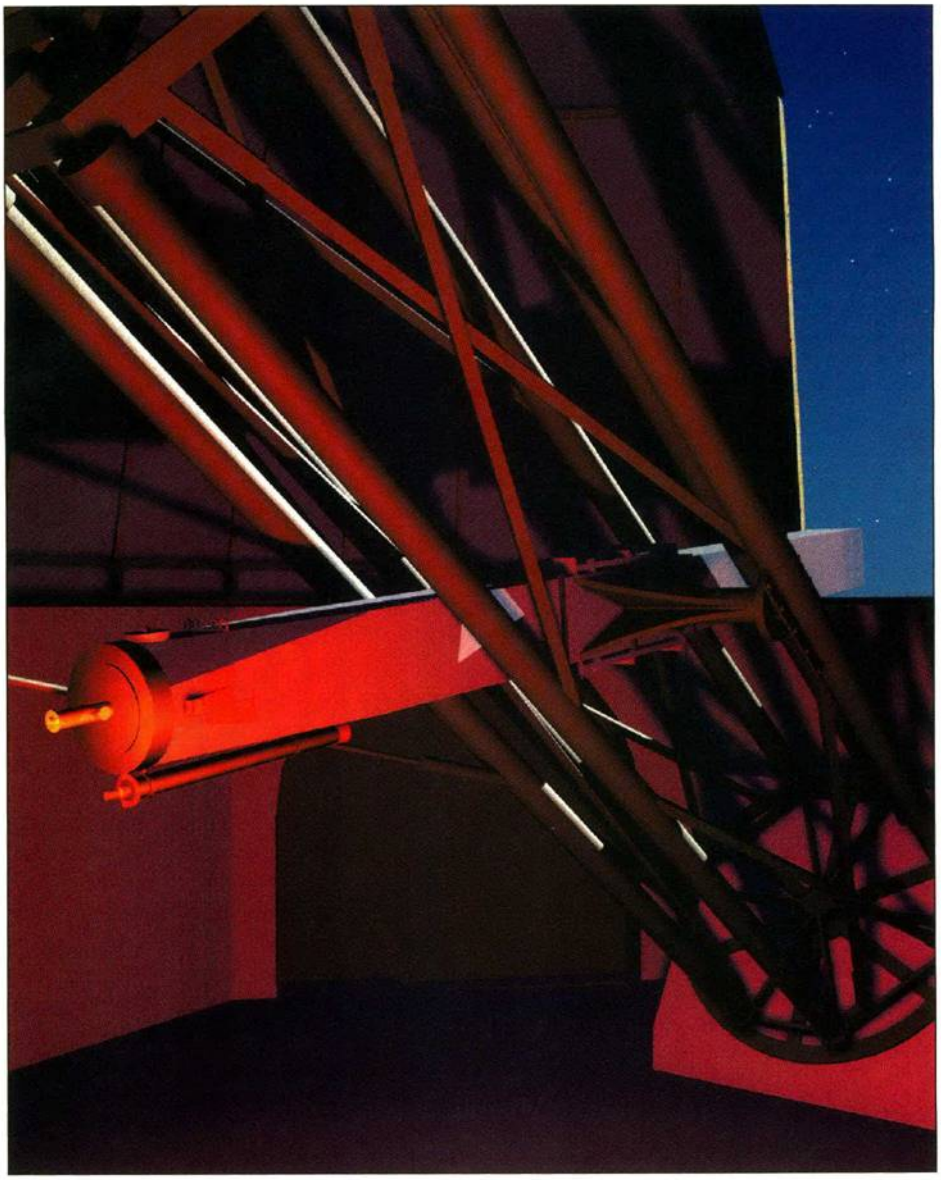
Adams had been obsessed with the problem of Uranus since July 1841. In February 1844, using James Challis, director of the Cambridge Observatory, as an intermediary, Adams wrote to obtain observations of Uranus from Sir George Biddell Airy, the Astronomer Royal at the Royal Greenwich Observatory. In September 1845, Adams shared his preliminary position of the planet with Challis. But neither Airy or Challis gave him more than polite encouragement. Moreover, neither encouraged Adams to publish his results.

Airy proved to be the crucial actor on which the whole drama came to turn. A good mathematician and a capable if rather despotic and rigid administrator, he has, largely because of his role in the Neptune affair, acquired the reputation of being an unimaginative and irascible bureaucrat. He seems to have felt that the role of the Royal Observatory was to precisely determine the positions of the Sun, Moon, and planets. Possibly he felt that other observing projects, including planet-hunting, should not interfere with this task. Airy was also deeply suspicious of theoretical predictions, and he distrusted young people, often treating his junior assistants badly.

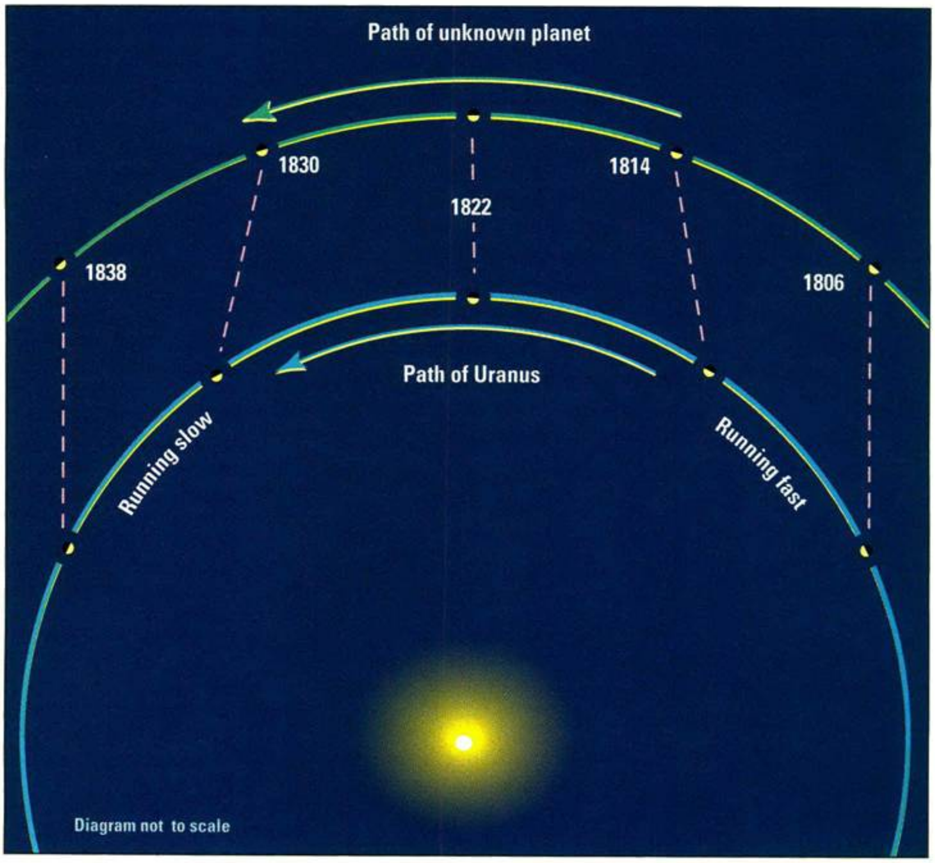
As a result Airy has taken most of the heat for the Neptune fiasco. He did, however, express an interest in what Adams was doing (which is more than can be said of most of Le Verrier's French colleagues), and he sent Adams the Greenwich observations of Uranus that he requested. In the fall of 1845, Adams attempted to visit Airy on two occasions while traveling between Cambridge and his home in Cornwall. However, he failed to announce his visits. On the first occasion Airy was away in France. On the second, Adams actually stopped by twice; in the morning Airy was out, and in the afternoon Airy was at dinner (Airy always ate punctually at 3:30 p.m., an unusual time even for that era) and his butler turned Adams away at the door.

Had Adams announced his visits, and had he actually met Airy in person, matters might well have taken a different turn. Though Adams left a summary of his calculations after his second visit, he went away feeling that he had been rebuffed. Two weeks later, Airy wrote Adams thanking him for leaving his calculations. Airy also asked Adams a technical question regarding Uranus' orbit that he felt was paramount in solving the discrepant orbital motion.

In a classic example of misunderstanding, Adams regarded Airy's question as having little importance.


Julian Baum

James Challis used the Cambridge Observatory's 11.7-inch Northumberland refractor to search for the new planet. He sighted Neptune twice before its discovery without recognizing it for what it was. He would have discovered Neptune if he had possessed an up-to-date star map.



ASTRONOMY: Lee Vande Visse

In the early 1800's Uranus was moving faster than predicted as it was catching up to the slower-moving Neptune. After Uranus passed Neptune in 1822, Neptune's gravity acted as a brake on Uranus' motion, causing it to move slower than predicted.

Adams felt that Airy was attempting to evade him. Feeling rebuffed for having been turned away at the door, Adams failed to respond to Airy, effectively terminating their correspondence for almost a year. Adams' failure to pursue the matter further cannot be laid solely at Airy's doorstep. One of his Cambridge colleagues later commented, with some justification, that Adams "acted like a bashful boy rather than like a man who had made a great discovery."

The older Le Verrier, unlike Adams, was already an established figure in science due in part to his brilliant work on Mercury's orbit. He was, moreover, a forceful personality. And whereas Adams' results were known only to Airy and Challis, Le Verrier published his planet prediction in June 1846.

On seeing the remarkable coincidence between Le Verrier's and Adams' predictions (they agreed to within half a degree — the diameter of a full Moon) Airy was at last stirred into action. He confidently announced on June 29, 1846, at a high-level meeting in Greenwich that included Challis and John Herschel, "the extreme probability of now discovering a new planet in a very short time, provided the powers of one observatory could be directed to search for it." Airy exchanged letters with Le Verrier. Le Verrier politely answered Airy's technical question, even though he, like Adams, found it to be irrelevant.

Airy quickly drew up a plan for a search, though interestingly, he said nothing about the search or Adams to Le Verrier. Airy claimed that none of the Royal Observatory's telescopes were large enough to detect the planet (the largest was the 6.7-inch Sheepshanks refractor), so he asked Challis to conduct a search with the Cambridge Observatory's 11.7-inch Northumberland refractor. (Perhaps the real reason for Airy's reluctance is that he did not want to bog down the Royal Observatory in time-consuming observations.) Airy advised Challis to map the stars in the region between Aquarius and Capricornus where Adams' and Le Verrier's calculations had placed the planet.

Challis, who was severely overworked, was at first unenthusiastic about the search. Indeed, with hindsight, Airy's instructions to him were better suited for making a star map than they were for a planet search. Rather than provide Challis with the predicted coordinates for the planet, Airy asked him to sweep broad swaths of sky 30° long and 10° wide and to look for a star as faint as 11th magnitude moving from night to night. But this area of sky encompasses more than 3,000 stars 11th magnitude or brighter.

Poor Challis didn't stand much of a chance. But he resolved to do his duty, and on July 29 he finally got underway. Clearly Challis was expecting a long siege. He went about his work in a rather perfunctory manner, not bothering to compare his observations from night to night. He was also preoccupied with observations of a new comet, which in his mind took higher priority. Challis later wrote, "It was so novel a thing to undertake observations in reliance upon merely theoretical deductions; and that while much labor was certain, success appeared very doubtful."

While Challis was plodding along, now came the missed opportunities that Herschel would later regret. In August 1846, Herschel paid a visit to his friend William Rutter Dawes, an amateur astronomer based near Liverpool. Herschel leaked information about the planet search. Herschel suggested that Dawes search for the planet himself with his 6-inch refractor, but conveyed the impression that it would not appear "until around Christmas." This might explain why Dawes failed to seize the initiative. Another possibility is that Dawes believed that the planet, if it existed, would only be visible in large telescopes. (In fact, it can be seen in binoculars, if one knows where to look.) Dawes did not search himself but instead passed the information along in a letter to his friend, William Lassell.

Mary Lea Shane Archives of the Lick Observatory

William Lassell

Lassell, a brewer by profession, had just completed work on a splendid 24-inch equatorially mounted reflector at his private observatory near Liverpool. Recognizing Lassell's superior equipment, Dawes confided to Lassell the probable position of the new planet and told him to search for a star with a disk.

Again, however, bad luck plagued the English. The story of Lassell's role in the events leading up to the discovery of Neptune comes from accounts by two astronomers, Edward S. Holden and Albert Marth, who interviewed Lassell's daughter 30 years after Neptune's discovery. This is perhaps the least-known sidelight of the Neptune story.

Apparently, Dawes wrote to Lassell only two weeks before the planet's actual discovery. When his letter arrived with the predicted position of the planet, a sprained ankle was confining Lassell to a sofa. The letter, unfortunately, was misplaced through the carelessness of a maid-servant (shades of Airy's butler).

Astronomical Society of the Pacific

Sir John Herschel

Lassell attempted to find the letter the following night, but was unsuccessful. By then, events were moving too quickly for him to keep pace. Before he could follow up with a letter to Dawes requesting the position that had been lost, the planet was within Galle's grasp, and England's last, best chance for a discovery had slipped away.

On reading the *Times* announcement on October 1, John Herschel penned a letter to the journal *Athenaeum*. This letter made the first public mention of Adams' name and his earlier but unpublished results. Herschel's belated announcement naturally angered the French, who felt the English were trying to steal Le Verrier's glory. The controversy over "Le Verrier's planet," or Neptune as it was soon being called (after the Greek and Roman god of the sea), was played out against a long background of Anglo-French tension and hostility. The two countries had been at odds for centuries — the Napoleonic Wars had ended only in 1815, and in recent times they had been involved in serious disagreements over affairs in Egypt and Spain.

As bitter words criss-crossed the English Channel, an indignant Le Verrier protested, "Why should Mr. Adams have maintained silence for so many months?"

On October 17, Challis published a candid account

Neptune Discovery Chronology

1781

Mar. 13 - William Herschel discovers Uranus

1821-22

Uranus and Neptune in conjunction

1841

July 3 - Adams resolves to solve Uranus problem

1843

Oct. - Adams makes preliminary orbit calculation

1845

June - Le Verrier begins work on Uranus problem

mid-Sep. - Adams reaches more detailed conclusion, planet only 2° from prediction, discusses prediction with Challis

Sep. 23 - Adams visits Airy, but Airy in France

Oct. 21 - Adams tries to visit Airy twice; the second time he is turned away from the door by Airy's butler

Nov. 5 - Airy writes Adams with question about Uranus' orbit; Adams never replies

Nov. 10 - Le Verrier announces first analysis of Uranus problem

1846

June 1 - Le Verrier publishes first new planet prediction

June 23 - Le Verrier's prediction reaches Airy; Airy notes similarity to Adams' prediction

June 26 - Airy begins correspondence with Le Verrier, includes Uranus question, never mentions Adams or search plans

June 29 - Airy announces to colleagues that new planet will soon be found, draws up plans for a search

July 9 - Airy writes Challis asking him to search for new planet

late July - Adams completes new calculations for planet

July 29 - Challis begins search for Neptune

Aug. - John Herschel leaks information about planet search to Dawes

Aug. 4 and 12 - Challis sights Neptune, but doesn't realize he sees a new planet

Aug. 31 - Le Verrier makes specific prediction to Paris Academy of Sciences, says the planet can be recognized by its disk

early Sep. - Dawes sends letter to Lassell containing prediction, but letter misplaced by maid-servant

Sep. 10 - John Herschel tells British scientists that planet discovery is imminent

Sep. 18 - Le Verrier writes to Galle requesting search

Sep. 23 - Le Verrier's letter reaches Galle; Galle and d'Arrest find Neptune after a mere 30 minutes of searching

Sep. 24 - Galle sees that Neptune has moved, confirming it is an object orbiting the Sun

Sep. 29 - Challis spots Neptune for third time without realizing it

Oct. 1 - news of Neptune's discovery reaches England of his search in the *Athenaeum* — confessing that he had recorded the unknown planet twice, on August 4 and 12, but had not gotten around to comparing the observations. Challis would have found the planet easily if only he had possessed the star chart that Galle used. Challis' account described Adams' work going back to 1843, but failed to even mention Le Verrier's name. The French were outraged, and newspapers in Paris vilified Airy, Challis, and Adams.

Both Challis and Airy came in for searing criticism in England as well for what seemed, in retrospect, their rather half-hearted efforts to follow up on Adams' promising lead. Even one of Airy's Cambridge friends exclaimed, "Oh! curse their narcotic Souls!" Adams and Le Verrier, however, did not participate in the nasty international priority dispute. They actually met in Oxford the following June without rivalry or bitterness and parted as lifelong friends.

In addition to the Adams bombshell, Herschel wrote another important letter on October 1. He wrote to Lassell, with whom he had been in correspondence about the satellites of Saturn. Herschel must have felt guilty that he had not directly informed the brewer-astronomer about the unknown planet. Now he wrote with considerable urgency: "Look out for satellites with all possible expedition!!" Something might yet be salvaged for England. If there were Neptunian satellites to be discovered, Lassell with his powerful telescope would be the man to do so.

Lassell indeed turned his reflector on the new planet, and on October 2 recorded that its small disk was surrounded by a ring. Then on October 10 he noticed a "star" whose "close situation . . . and minuteness . . . occasioned my strong suspicion that it may be a satellite." The ring proved to be illusory — it had nothing to do with the actual rings of the planet, which are far too wispy and faint to have been seen in Lassell's telescope. But Lassell had found a satellite, later named Triton, which he confirmed in July 1847.

One intriguing question remains. If Herschel had informed Lassell sooner of the position of the planet or if Dawes' letter had arrived at a more opportune moment, would Lassell have made the discovery

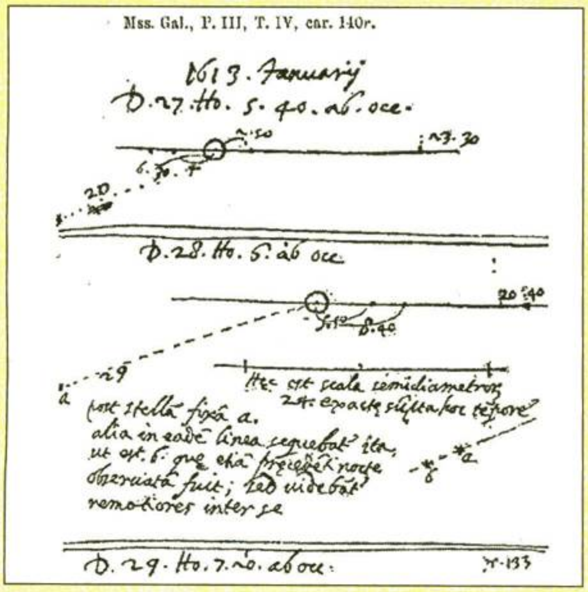
Eight Before Seven

Before Galle discovered Neptune on September 23, 1846, the planet had been seen — but not recognized — on several prior occasions. In addition to Challis' records of August 4 and 12, 1846, the French astronomer Michel de Lalande recorded it twice, on May 8 and 10, 1795. Scottish astronomer John Lamont stumbled across it unsuspectingly on October 25, 1845, and again on September 7 and 11, 1846. It was even passed over by John Herschel on July 14, 1830.

But by far the most intriguing prediscovery observations were made by Galileo Galilei at the dawn of the telescopic era. Galileo first sighted Neptune as an 8th-magnitude star on December 28, 1612, while tracking the newly discovered satellites of Jupiter. On January 27, 1613, he again mapped Neptune, then in a line with Jupiter, its satellites, and another star. He returned to the same field the following night and commented that the two "stars" appeared slightly farther apart. But he failed to follow up.

What if Galileo had recognized the planet in 1613? If so, the history of astronomy would have unfolded in a completely different fashion. Neptune would almost certainly have received another name. Galileo chose "Medicean Stars" for the satellites of Jupiter, after his patron Cosimo de'Medici II. He might well have named Neptune "Cosimo's Planet."

The discovery of a major planet so soon after the invention of the telescope would doubtless have prodded others — perhaps Galileo himself — to search systematically for additional planets. If so, Uranus would have turned up long before 1781 as a result of a direct search, not on the basis of theoretical prediction as was Neptune. Astronomers would have filled in the outer solar system in a different order, and astronomy would have been deprived of one its most dramatic stories and the discovery that has always been regarded as the crown jewel of its predictive powers.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133

Charles T. Kowal

Two hundred and thirty-three years before Neptune was discovered, Galileo spotted the planet while observing Jupiter. His notes indicate that he mistook Neptune for a star.

by sighting its small disk among the stars? We can never know for certain, but the answer seems very likely to be yes.

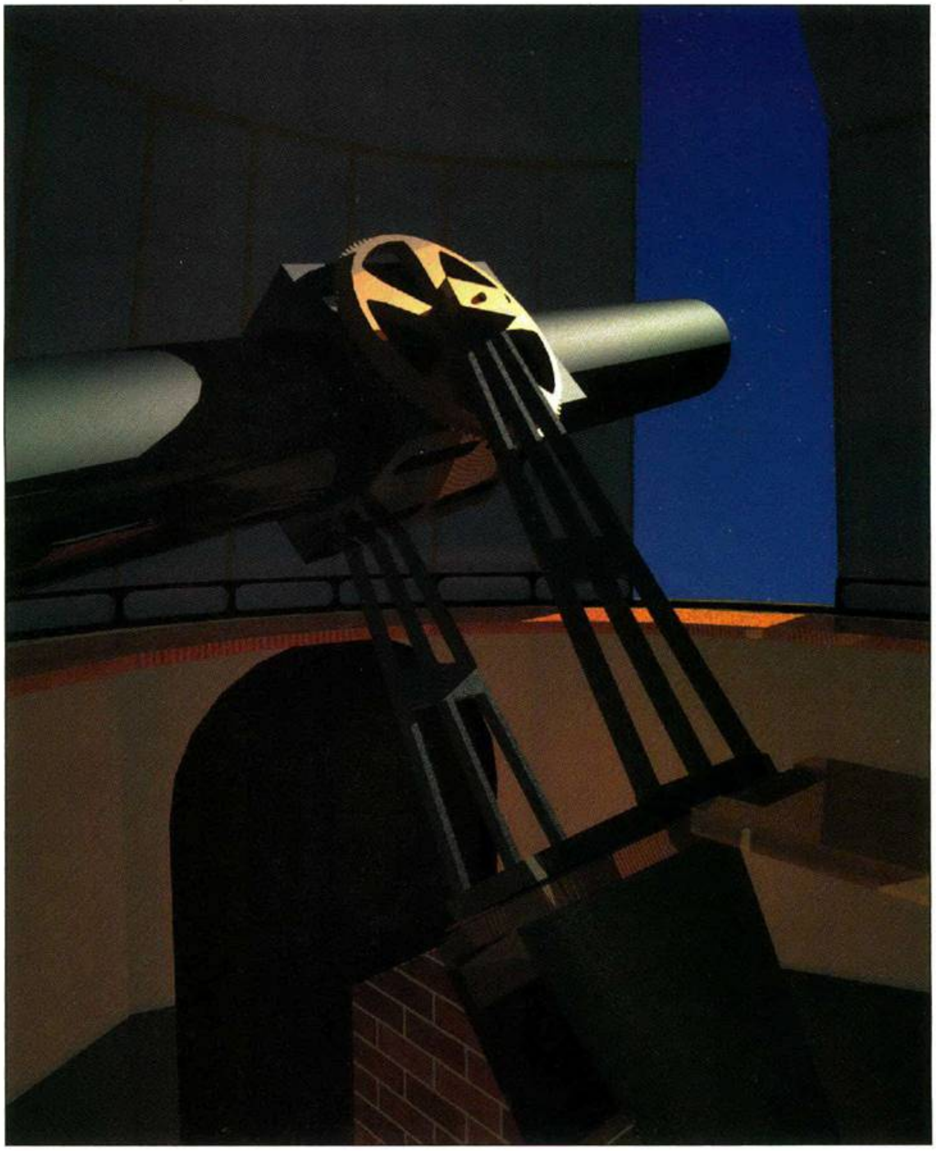
Galle at first had been unable to make out the disk, but he was sweeping with low power. After he and d'Arrest had recognized it, he is quoted as having said on examining it with higher power, "My God in heaven, this is a big fellow!" D'Arrest too, the night after the discovery, remarked on its disk: "There it is! There is the planet, with a disk as round, bright, and beautiful as that of Jupiter!"

Neptune's disk was well within range of Lassell's 24-inch reflector, and given his skill and diligence, he would have recognized it if only he had known where to look. You can just make out the disk with a 6-inch telescope, using magnifying powers of 300x to 400x. It is slightly larger than the disks of Jupiter's four Galilean satellites, which are another exacting test of small-telescope optics and seeing.

In a large instrument, such as the Lick 36-inch refractor, with a magnification of 1200x, Neptune appears satisfyingly round and planetary — like a cold-blue moon. It is distinctly bluish, in contrast with Uranus, which appears greenish. In recent years comparing the two planets has been convenient due to their proximity in the sky — they lie within a few degrees of each other, where in 1993 they passed their first mutual conjunction since 1821–22 (see "Moonwalking the Outer Planets," August 1996).

But it's sobering to realize that Neptune has yet to complete one circuit of the Sun since it was discovered; its period of revolution — the Neptunian "year" — is 165 Earth years. The first "Neptunian anniversary" of its discovery will not occur until 2011, when the planet will finally return to the same star field where Johann Galle found it in 1846.

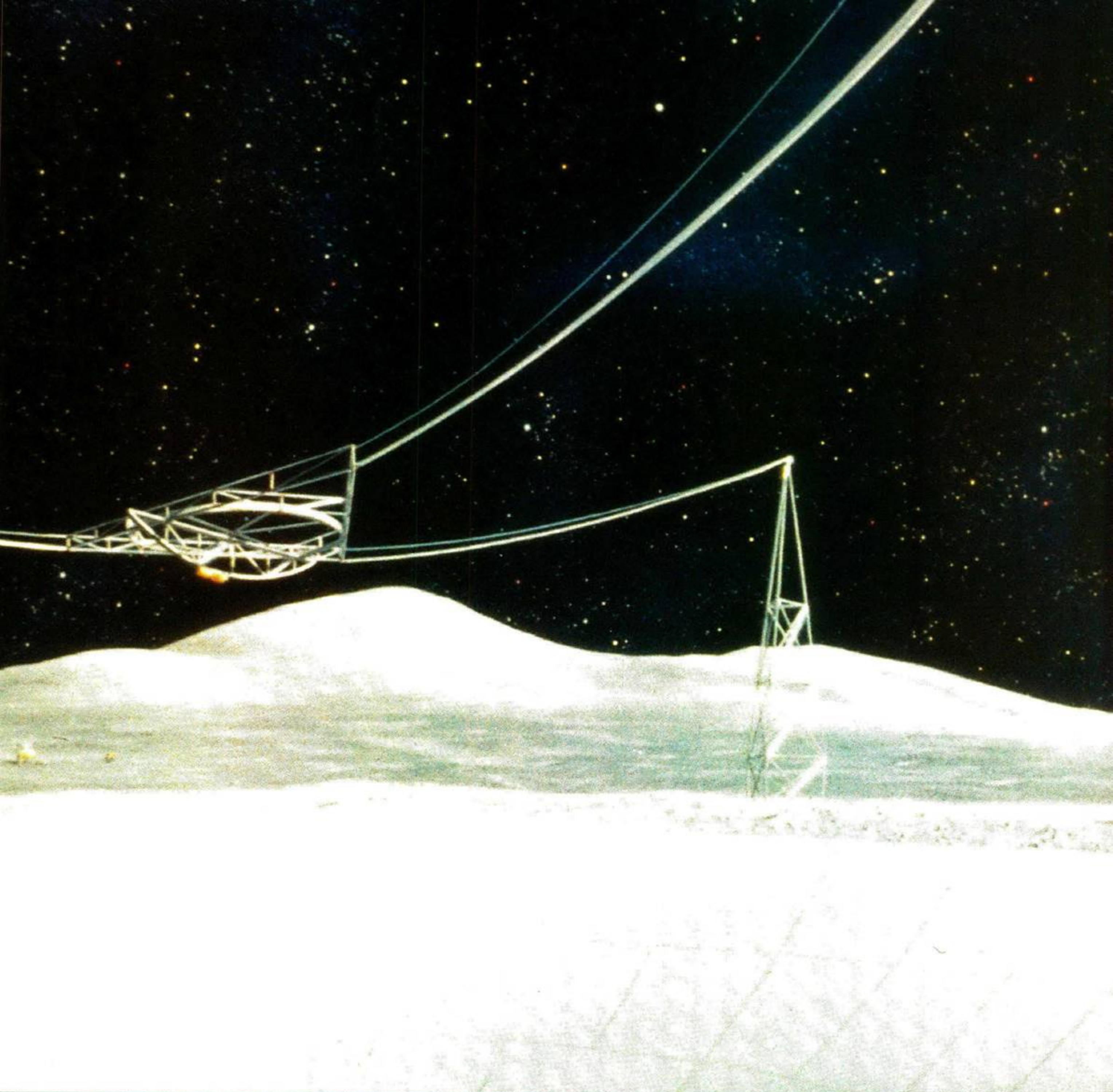
Even with a small telescope, it is always exciting to spot this portentous little disk among the stars, and to recall that as small as it seems, Neptune is a planet with a diameter four times that of Earth; a giant world massive enough for its influence to have been felt by mathematicians before it was seen in the telescope. Inevitably, one's mind returns to the thrilling days of a century and a half ago when Challis, Dawes, or Lassell might well have found it, but it fell instead to the deserving — and fortunate — Galle in Berlin. And d'Arrest's exclamation "That star is not on the map!" remains among the most ringing words uttered in the history of astronomy. ☐



Julian Baum

British amateur astronomer William Lassell, a brewer by profession, could have *easily* spotted Neptune's disk with his homemade 24-inch reflector if only he had possessed Adams' or Le Verrier's predicted coordinates. But a sprained ankle and a careless maid-servant prevented him from making the discovery. Lassell later discovered Neptune's moon Triton with this telescope, which was one of the finest of his era.

William Sheehan and Richard Baum are coauthors of a forthcoming book, Le Verrier's Wild Geese, *to be published by Plenum Press, which details the searches for Neptune and the intra-Mercurial planet Vulcan.*



Where's the ideal place to build an astronomical observatory?

If you asked a panel of astronomers, the first thing they'd say is to get it off Earth. The atmosphere distorts visible light coming from deep space and, in many wavelengths, it doesn't let the light get through at all. To get around this problem, astronomers developed orbiting observatories such as the Hubble Space Telescope, the Infrared Astronomical Satellite, and the Compton Gamma-Ray Observatory. These and other satellites have revolutionized modern astronomy.

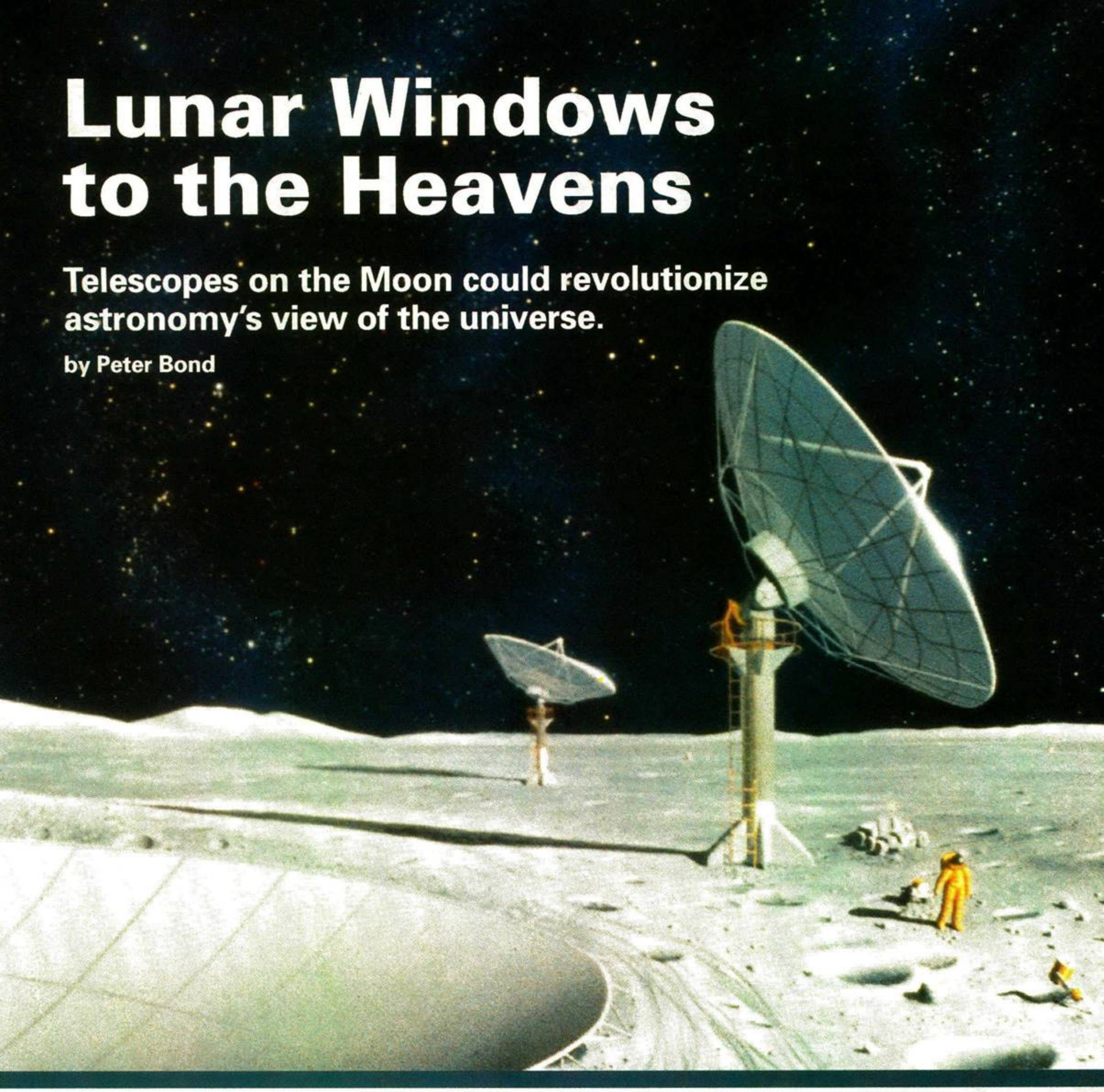
But astronomers would also want a stable platform. As satellites pass in and out of Earth's shadow, temperatures vary by 280° C. This causes the satellites to jiggle slightly, limiting the resolution that can be achieved.

A mere 384,000 kilometers away, however, lies a place that combines the advantages of a space-borne observatory with the rock-solid platform of Earth. This place is the Moon. Observatories on the Moon could open new windows to the heavens that will transform our perception of the universe. "The Moon is the obvious place for doing astronomy in the inner part of the solar system," says New Mexico State Uni-

Lunar Windows to the Heavens

Telescopes on the Moon could revolutionize astronomy's view of the universe.

by Peter Bond



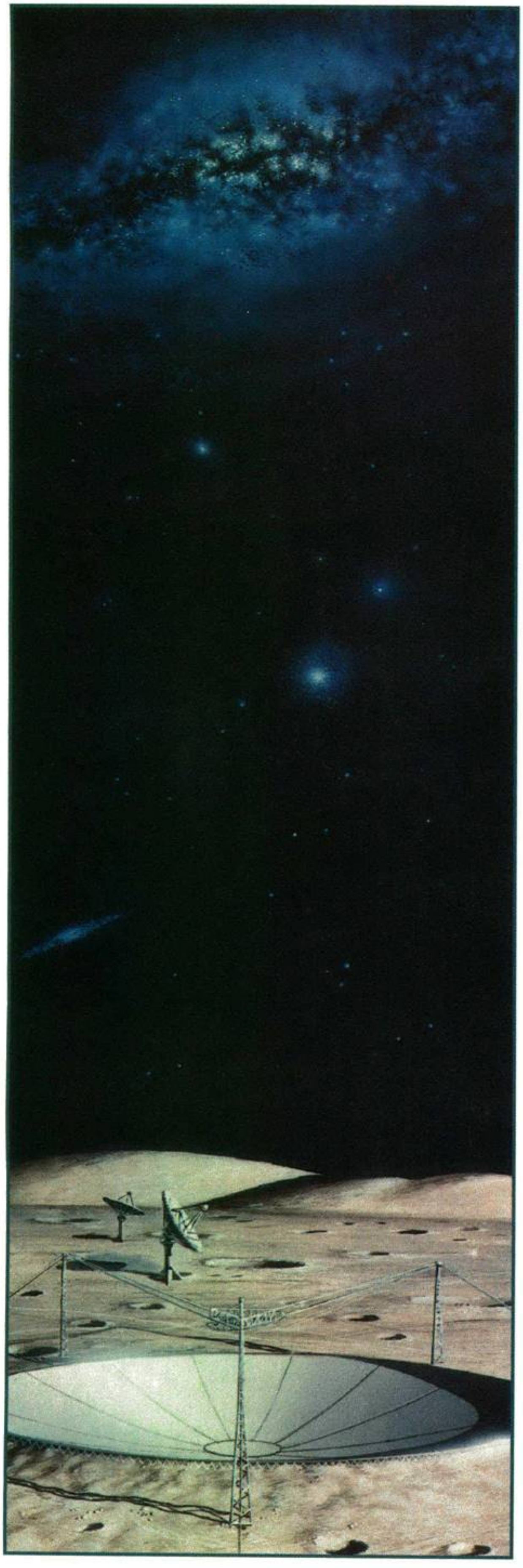
Pat Rawlings and NASA

versity astronomer Jack Burns, who has studied lunar observatories for many years.

The Moon as an Astronomical Base

Although orbiting observatories are cheaper than lunar observatories, the Moon clearly surpasses Earth orbit in a number of important areas. Besides the lack of jiggles, both optical and radio interference are hundreds of times lower on the Moon. Orbiting telescopes must also contend with light reflected by Earth. And the lunar farside is the quietest place in the inner solar system for radio astronomy because the Moon's solid body blocks the din of radio noise from Earth. Relay satellites in lunar orbit could transmit the data back to Earth with a delay time of less than 2 seconds.

When comparing the Moon to Earth's surface as an astronomical base, the Moon wins hands down. The Moon's atmosphere is so negligible that all of its "air" could fit inside a sports arena. With virtually no atmosphere, every wavelength of light, from the lowest frequency radio waves to the highest energy gamma rays, streams down unfiltered to the surface. Without an atmosphere to scatter light, the sky is cold and dark. Whereas terrestrial optical and infrared telescopes can operate only at night, lunar telescopes could operate round-the-clock.



Doug McLeod, Mark Dowman, and NASA

The Moon's orbital and physical characteristics provide a number of other advantages. Its slow rotation allows uninterrupted observations of faint objects for nearly two weeks, much longer than is possible from Earth (except at the poles) or in low-Earth orbit. The Moon's gravity is only one-sixth that of Earth, and yet it still has a stable, solid surface. Astronomers could use much larger and lighter mirrors without them being deformed by gravity.

A radio telescope similar to the 305-meter Arecibo Observatory in Puerto Rico could be constructed relatively easily by using the natural bowl shape of a large crater. And unlike in Earth-orbit, raw materials are right there — reducing the amount of material to be shipped from Earth. Lunar soil could be used for thermal insulation and radiation shielding, and possibly processed for building purposes.

On A Clear Day . . .

Because of the complexity and cost of establishing a lunar observatory, astronomers plan to start with small, unmanned, soft-landed telescopes that will serve as crucial precursors for gigantic arrays to be built by astronauts. Jack Burns calls this "an evolutionary approach versus a revolutionary approach."

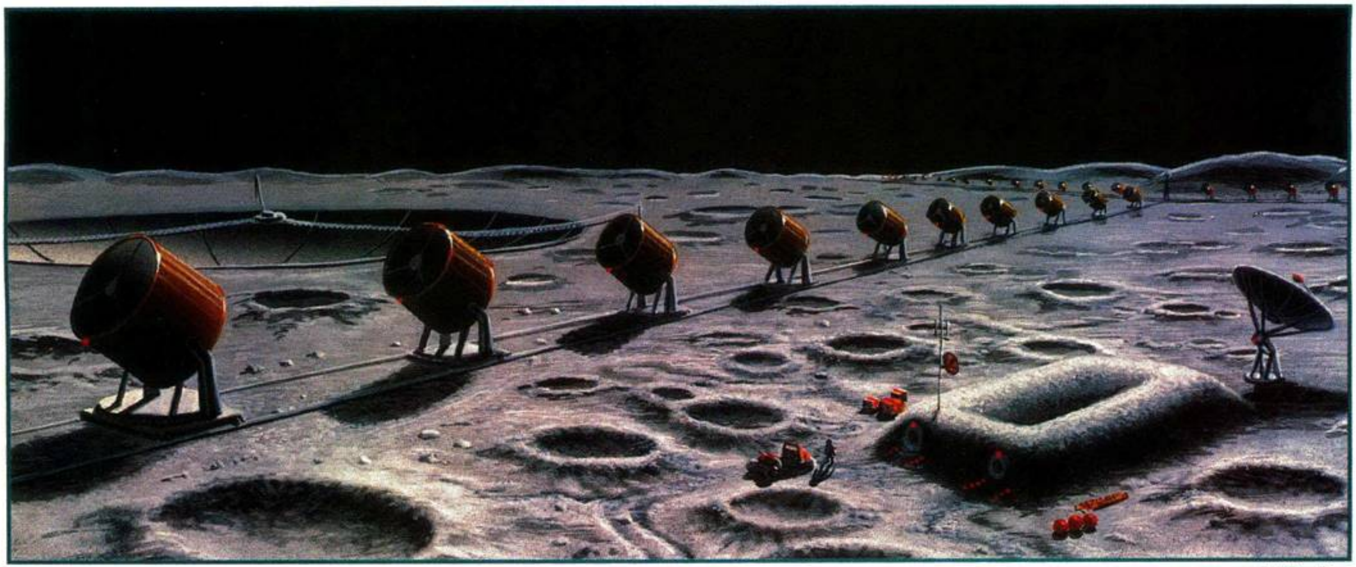
Apollo 16 astronauts took the first step in 1972 when they set up a 3-inch ultraviolet telescope on the Moon. This instrument observed a host of ultraviolet sources, including Earth's upper atmosphere and magnetosphere, the Large Magellanic Cloud, and the ultraviolet halos that surround galaxies.

As a follow-up, engineers at NASA's Marshall Space Flight Center in Huntsville, Alabama, designed a 1-meter instrument called LUTE (Lunar Ultraviolet Telescope Experiment). LUTE could be placed on the Moon by an automated lander and operated by remote control. Congress never funded it, however. LUTE would have had a fixed declination. As the Moon rotates, LUTE would sweep a 1.5° swath of sky, thus carrying out a limited deep sky survey in a far-ultraviolet wavelength that is difficult to observe from Earth or Earth orbit. "LUTE was an unmanned lunar mission that had tremendous scientific benefits," says Marshall engineer Max Nein. "It was a pathfinder for other telescopes to follow, you built up from it based on what you learned."

At infrared wavelengths, a 1-meter telescope could conduct important science while testing conditions for more advanced instruments. Currently planned space infrared telescopes are all modest in size (less than 85 centimeters in diameter) and are restricted to a two- to three-year operational lifetime. A lunar infrared telescope could take advantage of the near vacuum and the extended observation time to cover the sky for many years at much higher sensitivity than existing instruments.

Permanently shaded craters near the lunar poles would be ideal sites for infrared telescopes. Even at Earth's South Pole, where temperatures plummet to -90° C, infrared telescopes must be cooled even fur-

Large radio telescopes could fit inside lunar craters, forming the equivalent of the Arecibo antenna in Puerto Rico.



Pat Rawlings

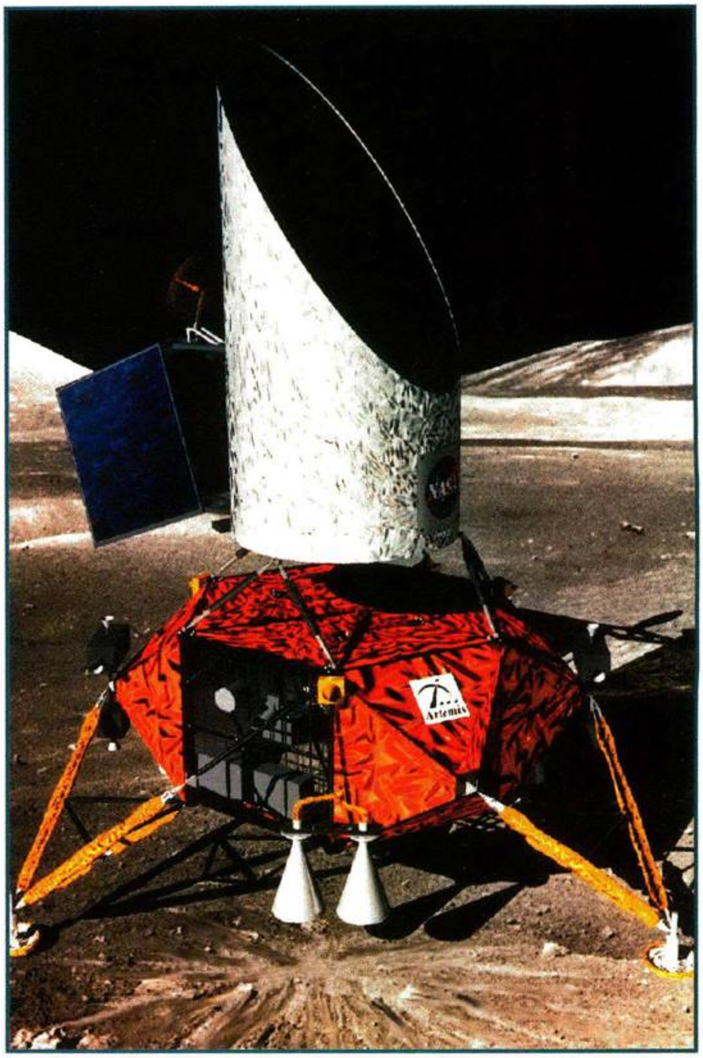
An array of lunar optical telescopes could take ultra-high resolution photographs of distant celestial objects.

ther by liquid nitrogen. This is necessary to reduce heat pollution that otherwise swamps the faint signal from distant infrared sources. But the frigid –200° C environment at the lunar poles would passively cool the electronics, the infrared detectors, and the telescope structure itself. Such a telescope could teach us more about newly forming and low-mass stars (including brown dwarfs), aid in the search for dark matter, and detect primeval galaxies that are so far away that the expanding universe has stretched their visible light into the infrared.

Still another lunar detector could survey the entire sky at X-ray or gamma-ray wavelengths. Fairly simple instruments could scan the sky for gamma-ray bursts. Astronomers could combine the lunar results with those from instruments on satellites and Earth to pinpoint the bursts to arcsecond precision. This might once and for all solve the gamma-ray burst mystery (see "Gamma-Ray Bursters: Near or Far?" December 1995). X-ray and gamma-ray telescopes could also link up with telescopes operating at other wavelengths to look at small, active regions such as the ones that surround supermassive black holes. This would help astronomers understand the violent processes that give rise to quasars and ultra-bright galactic nuclei.

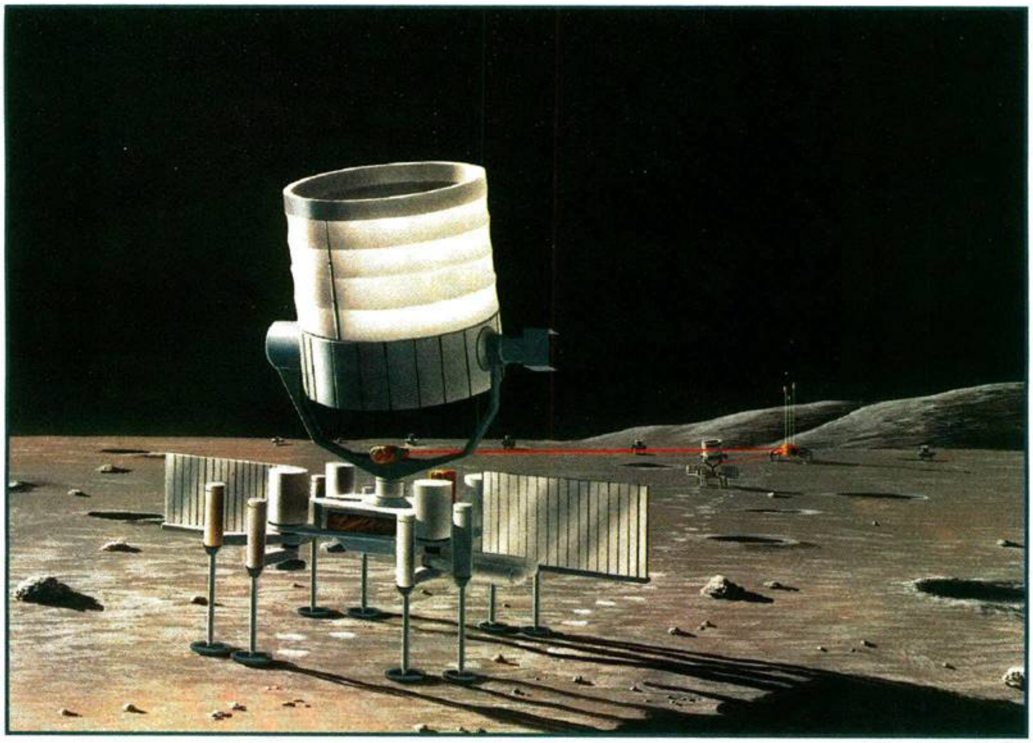
At visual wavelengths, even a lunar telescope as small as 1 meter would have a resolution of about 0.1 arcsecond, which is just about as sharp as the resolution of the 2.4-meter Hubble Space Telescope. Measurements of brightness changes in objects such as variable stars and quasars would require less than 1 percent of the exposure time required on Earth while avoiding the interruptions caused by cloud cover and the day-night cycle.

The lunar farside could open up a window to very-low-frequency radio astronomy, covering frequencies below about 15 megahertz (or wavelengths longer than 20 meters). Molecules in Earth's upper atmosphere absorb or scatter these waves before they reach the ground, so this is one of the few remaining unexplored regions of the electromagnetic spectrum. Astronomers could probe the nature and density of gas in interstellar space and learn how particles are



NASA/Marshall Space Flight Center

NASA engineers designed the LUTE ultraviolet telescope to land and operate by remote control.



Pat Rawlings and NASA

Since the Moon lacks an atmosphere, optics must be protected from tiny meteoroids by domes or tubes.

accelerated in quasars and radio galaxies. And as Burns points out, "Based on the history of astronomy, there's always something new when you open up a window for the first time."

Interferometry

Astronomers' ultimate goal is to build enormous telescope arrays on the lunar surface. By electronically linking together entire networks of small lunar telescopes, astronomers can achieve the resolving power of an enormous telescope, a technique called interferometry. For example, radio astronomers have successfully employed radio telescopes on opposite sides of Earth to simulate the resolving power of a hypothetical radio telescope as big as the planet.

Astronomy Sites Compared

	Earth	Earth Orbit	Moon
No atmosphere		✓	✓
Stability	✓		✓
Radio quiet			✓
Low heat background		✓	✓
Uninterrupted observing			✓
Low gravity		✓	✓
On-site materials	✓		✓
Low cost	✓	✓	
Magnetic field protection	✓	✓	
Stable temperatures	✓		
Low meteorite risk	✓		

Because infrared and optical interferometers require extremely stable conditions, atmospheric turbulence and seismic activity limit the size of such interferometers on Earth. Orbiting interferometers pose difficulties because each telescope is constantly in motion, whereas the distance between telescopes must be known precisely for interferometry to work. With the Moon's minimal seismic activity and lack of atmosphere, interferometers can achieve staggering improvements in resolution — unleashing the full potential of lunar astronomy.

Bernard Burke of MIT has outlined a step-by-step process for establishing a lunar interferometer. "You would start by putting up a telescope that's a prototype for the elements of an interferometer. Then after operating it and making sure you have a good and reliable design, then you proceed to send up a second telescope, so you have a two-element interferometer, still doing it robotically. When you go to the complexity of a many-element system, then you would need a manned base."

Two telescopes set up robotically one kilometer apart could beat the resolving power of the Hubble Space Telescope by a factor of 420. Such an interferometer could measure the distance of individual stars to a precision of 0.02 milliarcsecond, the width of a penny seen at 2 million kilometers. These measurements would enable astronomers to detect unseen companions such as planets and brown dwarfs.

Looking further into the future, Burke has proposed using lunar materials to build an array of 27 optical telescopes over a 16 km stretch of the surface. By taking advantage of the low gravity, lunar glasses could be cast into giant, high-quality mirrors. Such an optical interferometer, says Burke, would be capable of imaging sunspots on stars 300 light-years away.

A group led by Jack Burns designed an interferometer named LOUISA (Lunar-Optical-Ultraviolet-Infrared Synthesis Array). It would consist of two concentric rings of 1.5-meter telescopes. The outer ring would consist of 33 telescopes in a circle 10 km across. The inner ring would be only 0.5 km across and would contain nine instruments. LOUISA could observe wavelengths ranging from the ultraviolet (0.1 micrometer) to the infrared (1 micrometer). Such a complex would have a spatial resolution 100,000 times better than the largest ground-based telescopes and 10,000 times better than the Hubble Space Telescope, meaning it could see details in accretion disks around black holes, image Earth-like planets orbiting other stars, and even take the spectra of these planets to look for the chemical signature of life.

Astronomers dream of radio telescopes spread across the lunar farside, linked together as an interferometer. Such an array would be able to study in unprecedented detail emissions from objects such as quasars, radio galaxies, radio halos around galaxy clusters, pulsars, supernova remnants, and planets. "One could potentially use this to measure proper motions of galaxies in clusters," says Burns. "From this, you could determine galaxy distances directly and therefore make a new measurement of the universe's rate of expansion."

Practical Problems

Despite all of these advantages, there are a number of drawbacks to building astronomical observatories on the Moon. Whereas Earth's magnetic field protects us from cosmic rays and the solar wind, the Moon has no such barrier. Human construction teams and scientists, as well as sensitive electronics, would have to be shielded against radiation exposure.

The Moon lacks an atmosphere to incinerate incoming meteoroids. Impacts form about 100 tiny craters larger than 0.05 mm per square meter per year, so delicate surfaces such as mirrors must be protected by domes or tubes.

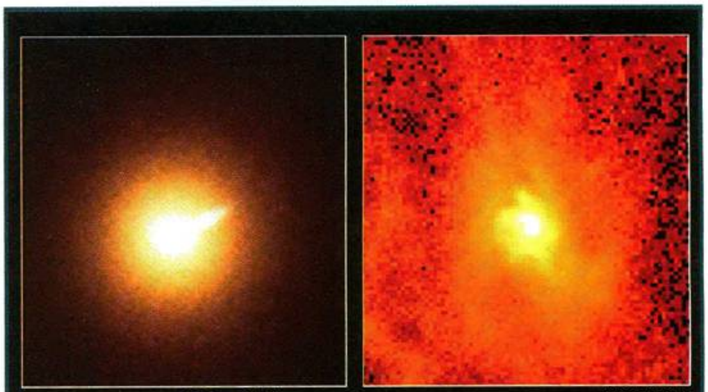
The long days and nights and the lunar vacuum combine to create drastic changes in temperature ranging from –170° C to 110° C. Telescopes will have to be built of new composite materials resistant to thermal expansion and contraction.

As the Apollo astronauts found to their annoyance, the lunar desert is coated with gray dust that clings to any surface. Human activity near a lunar observatory would clearly need to be minimized, and all sensitive surfaces would have to be protected from dust while the instruments are being deployed.

But of course the most significant problems are distance and cost. As Burns notes, "The Moon will probably be 10 to 100 times more costly for astronomical telescopes of a given aperture than Earth-based systems."

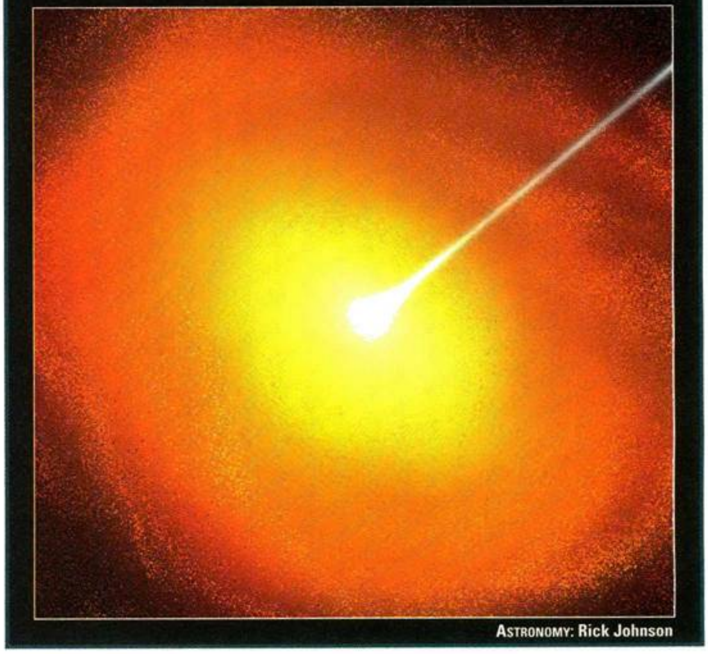
Burns believes that major progress in utilizing the Moon for astronomical purposes will only come after humans return there. "Once a human base is established and regular transportation to the Moon is present, the cost of doing science from the Moon will drop. At that time, it will be feasible to consider some of the imaginative 'grand' observatories that have been proposed for the Moon. For the next decade or two, however, national and international budgetary pressures mean that only modest, robotic telescopes on the lunar surface are feasible."

Because of the high costs involved, almost all lunar observatory advocates think the construction of lunar interferometers will require international cooperation in conjunction with a permanent human presence on the Moon. Because of major budget cutbacks in the United States, NASA appears to be out of the picture for the time being. Currently, the European Space Agency and the Japanese space agency NASDA have done the most significant planning. Both agencies have envisioned a phased approach starting with lunar robotic exploration followed by a permanent robotic presence on the surface, including some astronomical instruments. The construction of a human outpost would occur at the end of the process.



McDonald Observatory NASA/STScI

A ground based image (upper left) captures the entire galaxy M87, but provides no details of the inner region. In a Hubble Space Telescope image (upper right), we see the galaxy's inner regions, where a supermassive black hole lurks. A lunar interferometer could image the black hole's accretion disk (bottom).



ASTRONOMY: Rick Johnson

While the full potential astronomical potential of the Moon will probably remain untapped for two or three more decades, Burns concludes, "I can guarantee you that this will happen at some point. It is such an obvious place to go in space and such an obvious thing to do astronomically that I have high confidence that it will happen. What I don't know is *when* it will happen." □

Peter Bond writes about space and astronomy from his home in Cranleigh, England. His latest book, Reaching For The Stars, *is published by Cassell.*

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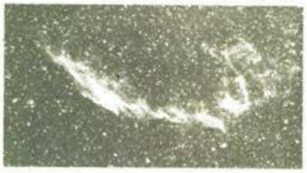

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Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
Adapter for Hasselblad **$225,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10-12" Meade. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ...... **add $99.95**
Adapter for Hasselblad **$295,** Mamiya 645**$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** ... **$109.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, pulsed.
2. **Cable release** for long exposures **$9.95**
3. **Declination motor** (state telescope type) **$109**
4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.
5. **LUMICON EASY-GUIDER** (selection to left)
6. **LUMICON 48mm DEEP-SKY FILTER** **$119.50**
This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

HYPERSENSITIZED FILM

SR1600
Scotch
1000
TP 135-36

HYPERED FILM IS 2-10X FASTER!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	$11.95
SR-G3200, fastest of all, color neg	24	$14.95
Kodak Gold 1000 fast, fine grain	12	$13.95
Fuji G800 fine grain color neg.	**24**	$13.95
Ektachrome 1600, fast slide film	24	$14.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

WRITE NO. 44 ON THE READER SERVICE CARD

LUMICON® ACCESSORIES | MEADE® TELESCOPES

TOLL-FREE ORDER LINE 1-800-767-9576 EXPERT INFORMATION 1-510-447-9570 FAX 1-510-447-9589
LUMICON, 2111 Research Drive, Suites 4-5, Livermore, CA 94550 OPEN M-F 9-5, SAT 9-1 PST

LED FLASHLIGHT . $14.95

LUMICON LUMILITE™ Red LED Flashlight

This red LED flashlight preserves night vision. It uses 2 AA cells (included!) which last 60-100 hours.

LUMILITE red LED flashlight	**$14.95**

DRIVE CORRECTORS

LUMICON UNITRAK DRIVE CORRECTOR

Operate your telescopes ***anywhere!*** Use the single-axis Unitrak with a 12V DC car battery. The dual-axis drives are for photography and use either 12V DC or 125V AC.

Unitrak™ single-axis corrector	**$99.95**
Unitrak with hand controller	**$139**
Convenient rechargeable Porta-Pac battery: 12V DC Porta-Pac (5AH) & recharger	**$89.50**

48MM COLORED FILTERS
FOR EVERY NEED

Select 48mm UV, Red, Yellow, Green (ea.)	**$24.00**
48mm Cyan (absorbs red)	**$69.00**
48mm High Performance Blue (95% T)	**$59.00**
48mm Tri-Color Blue (80% T- 400nm) .	**$59.00**
48mm Ultraviolet (85% T- 370nm)	**$59.00**
Color Separation Set: cyan, red, yellow, blue	**$159**

RICH FIELD! 2° in 8'' SCT

NOW ONLY
$99.50

LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm or 80mm clear aperture for **totally unvignetted viewing** with 2'' or 1¼'' eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer	**$99.50**
Giant Rich-Field Viewer (10-14'') ..	**$250.00**

Optional Eyepiece	**TRUE FIELD**	**Price**
Meade 32mm Plossl	1.4°	**add $99**
Meade 32mm 2'' Wide-Field†	1.9°	**add $459**
Meade 40mm 2'' Wide-Field†	2.4°	**add $519**

†Includes 2'' enhanced aluminum Star Diagonal (may not reach focus on some telescopes).

PROTECTIVE DUST COVERS

Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼'' O.D. plug, seals focuser	**4/$2**		
2'' O.D. plug	**2/$2**	3½'' O.D. plug	**$1.50**
1¼'', 1⅜'' ...	**3/$2**	7½''	**$10**
1½''	**2/$2**	9½'', 10.4''*	**$15**
2''	**2/$2**	12½'', 12⅞''* ...	**$20**
2⅛''	**2/$20**	15.0'', 15.6'', 16''*	**$28**
5½''	**$6**	19'' (DS-16)	**$35**
*Fits Odyssey		21'' (Odyssey-II)	**$35**

MEADE 7'' - 16'' LX200
NEW! 7'' - 10'' LX50

8'' LX50
$1395

16'' LX200 $14,950

Meade 8'' LX200 Telescopes

LX50 - includes dec. motor, hand controller.
LX200 - full computer control w/64K obj. mem.
Tripod: extra for LX50; included for LX200

NOTE: A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your LX200.

NEW! 3.5'' f/14 ETX Maksutov ($20)	**$495**
NEW! 8'' LX50 w/wedge ($105 P&S) ..	**$1395**
Tripod for 8'', 10'' LX50 ($30 P&S)	**$295**
8'' LX200 w/computer ($105 P&S)	**$2795**
Wedge for photographing w/8'' LX200 ..	**$139**
7'' LX50 f/15 Maksutov w/wedge ($125 P&S)	**$1795**
10'' LX50, f/10 w/wedge, dec. motor, hand controller ($145 P&S)	**$1695**
10'' LX200 w/computer ($145 P&S)	**$3195**
12'' LX200 (f/10 only)($215 P&S)	**$4495**
Super Wedge for photogr. w/10'',12'' LX200	**$395**
16'' LX200 f/10 w/tripod ($385 P&S) .	**$14,950**
Dew Shields: 8'' .... **$119;** 10''	**$129**
12'' .... **$189;** 16''	**$289**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4'' f/10 w/motor ($40 P&S)	**$699**
Model 2120B 10'' w/wedge, tripod ($75)	**$1699**

PHOTOGRAPHY ACCESSORIES

Cassegrain EASY-GUIDER 4'', 8'', f/6 or f/10	**$249**
Giant EASY-GUIDER for 10''/12'' f/4-f/10 .	**$395**

MEADE STARFINDERS

8'' f/6
$749

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive & finderscope (equat. only), mount, and 25mm (=48X) eyepiece. New DC motor runs on 4AA batteries.

6'' f/8 Dobsonian Starfinder ($46 P&S)	**$349**
6'' f/8 Equat. Starfinder 6(add $79 P&S) ...	**$649**
8'' f/6 Dobsonian Starfinder (add $59 P&S)	**$469**
8'' f/6 Equat. Starfinder 8 (add $89 P&S) ...	**$749**
10'' f/4.5 Dobsonian Starfinder ($85 P&S) ..	**$649**
10'' f/4.5 Equat. Starfinder 10 (add $99 P&S)	**$879**
12.5'' f/4.8 Dobsonian Starfinder ($95 P&S)	**$895**
16'' f/4.5 Dobsonian Starfinder (freight COD)	**$1195**
16'' f/4.5 Starfinder 16 (ship. freight COD) .	**$2695**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

LUMICON Single axis drive corrector .	**$99**
Magellan computer; specify Dob. or Eq. ($15 ship)	**$295**
Meade 47M Dual-axis drive corrector with tangent arm & electric declination ..	**$475**

SKY VECTOR™ $299!!
Includes Computer, Encoders, Hardware

LOW PRICE—from $299

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $299

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $349

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $439

IMPROVED!—5500 Additions / Corrections

NGC-Sky Vector™
OFF ON
DIM
MODE
ENTER
UP
DOWN
LUMICON®

NGC SKY VECTOR with IDENTIFY (Sky Tour) mode, 12,000 object memory including the corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth, Meade 6-16'' Dobsonian.

Ultima 8, 9¼, 11 **add $25**, C-14 **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2'' EASY-GUIDER .	**$189.50**
2'' EASY-GUIDER (Mamiya 645)	**$239.50**
2'' Adapter for Pentax 6X7 ...	**$129.00**
2'' Adapter for Hasselblad .	**$229.00**
2'' Adapter for Bronica SQ-A	**$175.00**
2'' Extension for viewing ...	**$26.00**

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow)	**$259.00**

LUMICON ACCESSORIES
LUMICON, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

LARGE UV/DUST SEAL

Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080 ...	**$119.50**
UV/Dust Deal for Celestron C-8 ...	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14 .	**$89.50**

LOW PROFILE FOCUSERS
New! Thread-on for Odyssey
FROM $69.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	**$69.50**
LUMICON 2'' Helical Focuser 1½'' high	**$75.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2'' Astro Systems focuser, only 2'' high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2''/1¼'' adapter w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$189.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$69.50**, 45°version	**$69.50**
1¼'' straight-thru 80mm SUPER-FINDER .	**$189.50**
1¼'' right-angle 80mm SUPER-FINDER ..	**$199.50**
1¼'' right-angle version, w/star diagonal ..	**$239.50**
25mm Cross-hair 1¼'' eyepiece (12X)	**$59.00**
Large mounting rings for 80mm Finder	**$55.00**
1¼'' Star Diagonal **$49**, Mounting Brackets,	**$39.50**
1¼'' 45° diagonal for correct left-right views	**$59.50**

LOTS OF ADAPTERS

2'' adapter for C-8, Meade 2080, etc. ..	**$29.50**
2'' adapter for C-80, C-100 refractor ...	**$39.50**
2'' adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2'' adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1'' long 1¼'' OD thread-in extension	12.00
2½'' long extension (holds 1¼'' filters) .	19.50
4½'' long extension for 1¼'' eyepieces	**$29.00**
3'' long extension for 2'' eyepieces* ..	**$29.00**
2'' long extension for 2'' eyepieces* ..	**$29.00**

VIEWING ADAPTERS

2''/1¼'' reducing bushing, threaded 48mm*	**$25.00**
2''/T-thread adapter, threaded 48mm* ..	**$25.00**
T-thread/1¼'' adapter	**$25.00**
F/10 2'' or 1¼'' eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2'' Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

WRITE NO. 44 ON THE READER SERVICE CARD

SKY
ALMANAC

September presents the last total lunar eclipse for North America until 2000. Mars and Jupiter drift along the fringes of two notable Messier star clusters.

by Martin Ratcliffe

Highlights
by Alister Ling

Date	Event
9	Morning's Celestial Necklace .....(p. 66)
20	**First Views:** Pull an All-Nighter....(p. 64)
26	Plumb Earth's Shadow ......(p. 63)
26	Saturn Rings In Opposition ....(p. 66)
all month:	**Observer's Challenge:** Planetesimals in Capricornus ....(p. 64)
	Autumn's Harvest of Comets ......(p. 67)

For the second time this year North American observers enjoy a total eclipse of the Moon. On September 26, at 9:12 p.m. Eastern Daylight Time, the Harvest Moon begins its slow trek through Earth's shadow. This time, unlike the last eclipse on April 3, totality is visible from the entire continental United States. Adding to the spectacle, Saturn sits just 3° to the south-southeast of the eclipsed Moon.

The Moon's path for this eclipse doesn't dig as deep into Earth's shadow as last April's eclipse. That means this eclipse will be both lighter and shorter, lasting 70 minutes compared with April's 90-minute totality.

Eclipse watchers living east of Kansas City's longitude savor all the partial phases up to totality.

The first umbral bite out of the Moon will happen at 9:12 p.m. EDT. But start watching an hour before, at 8:12 p.m. EDT, when our Moon starts slipping into the lighter, penumbral part of Earth's 16,000-km-wide shadow. The Moon's lower left quadrant will begin to subtly darken.

Once the darker umbral partial phases begin, you might notice how Earth casts a circular shadow onto the Moon. As the ancient Greeks discovered, this characteristic of all lunar eclipses is proof the Earth is a globe.

A small telescope will let you watch the Earth's shadow creep over craters and mountain ranges, plunging them into darkness (see the project box). As totality approaches, the darkness begins to take on an orange hue, perhaps a little gray in parts.

For west-coast observers , the Moon rises a half-hour before totality, already partially eclipsed. For San Francisco, moonrise is 6:53 p.m. PDT, with the onset of totality occurring at 7:19 p.m. PDT.

Farther east, the Moon rises earlier. For example, in Tucson moonrise is minutes before partiality begins at 6:12 p.m. MDT. By the time the Moon clears the horizon, totality will have already begun.

Totality arrives at 10:19 p.m. EDT, when the darkest part of Earth's shadow envelopes the Moon. During this stage, the Moon's northern limb will take on a bright orange appearance as Earth's atmosphere

Jerry Schad

Subtle colorplay shimmers across the Moon's face as it slowly crawls through Earth's 16,000-km-wide shadow. November 1993's lunar eclipse (left) had muted reds with magenta highlights. What will this month's spectacle look like to you?

1996
SEPTEMBER

2 Venus passes 9° south of Pollux, 1 a.m. EDT

3 Jupiter is stationary, 10 a.m. EDT

4 The Moon passes 0.9° north of Aldebaran, 10 a.m. EDT
Venus passes 3° south of Mars, 11 a.m. EDT
Last quarter Moon is at 3:06 p.m. EDT

7 Asteroid Thyra is at opposition

8 The Moon passes 6° south of Mars, 3 p.m. EDT
The Moon passes 3° south of Venus, 7 p.m. EDT
The Moon is at apogee (405,735 kilometers from Earth), 9:47 p.m. EDT

12 New Moon is at 7:07 p.m. EDT

17 Mercury is in inferior conjunction, 9 a.m. EDT

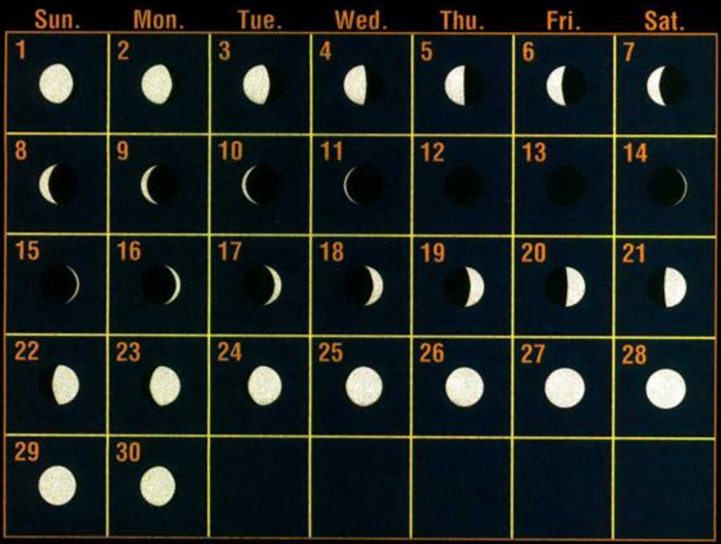
20 First quarter Moon is at 7:23 a.m. EDT

21 The Moon passes 6° north of Jupiter, 2 a.m. EDT

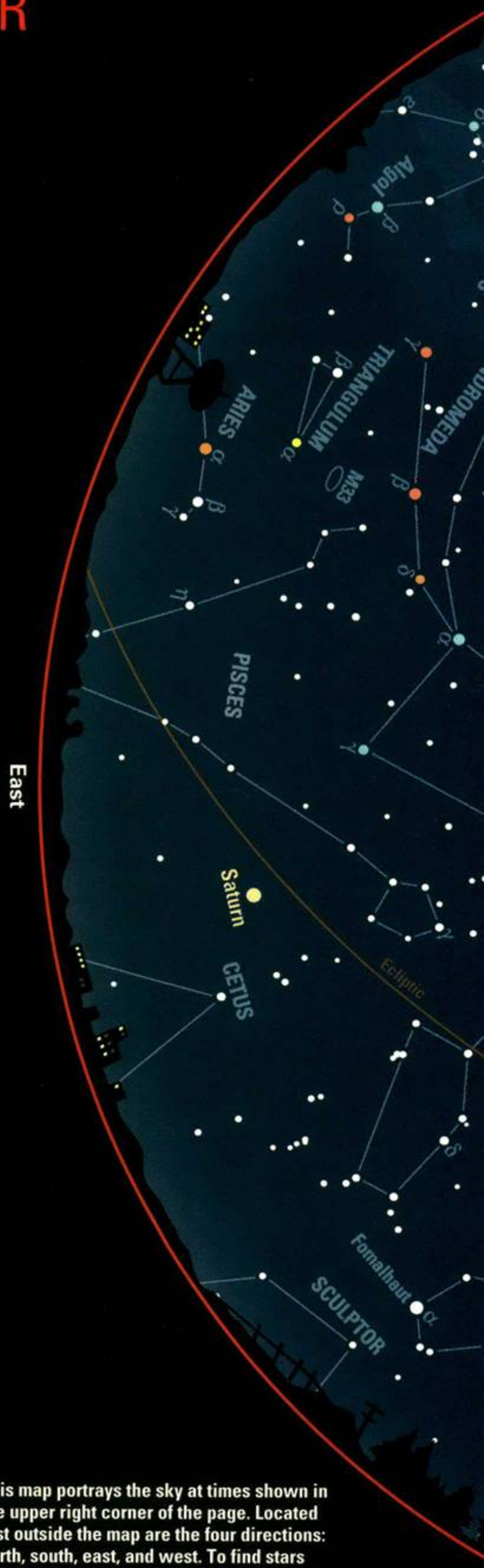
22 The Moon passes 5° north of Neptune, 7 a.m. EDT
Autumnal equinox is at 2:00 p.m. EDT
The Moon passes 6° north of Uranus, 5 p.m. EDT

24 The Moon is at perigee (363,053 kilometers from Earth), 5:44 p.m. EDT

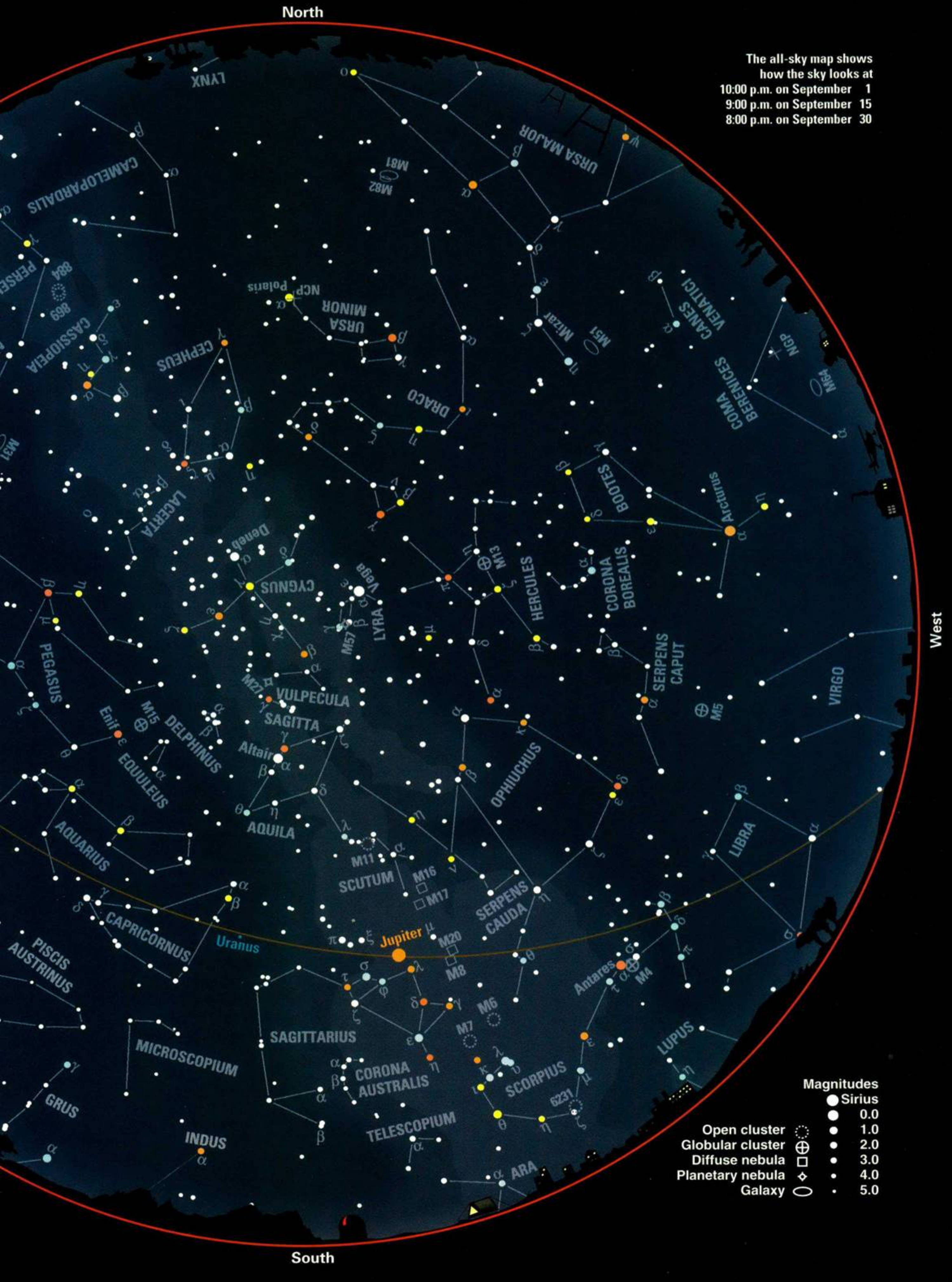
26 Saturn is at opposition, 3 p.m. EDT (page 66)
Full Moon is at 10:51 p.m. EDT; total lunar eclipse (page 63)
The Moon passes 3° north of Saturn, midnight EDT



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					



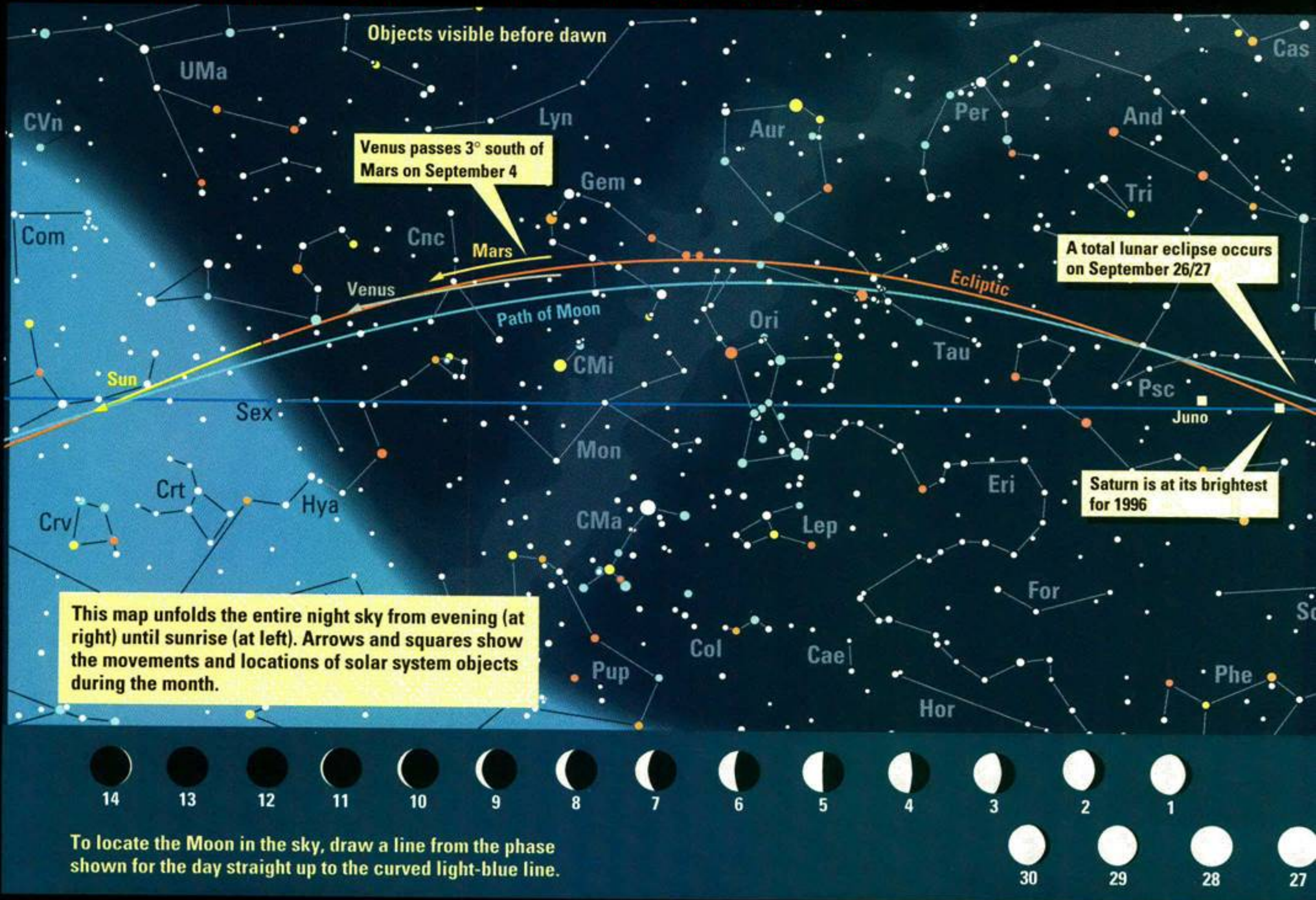
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.



North
South
West
LYNX
URSA MAJOR
CAMELOPARDALIS
M81
M82
NCP
Polaris
URSA MINOR
PERSEUS
884
869
CASSIOPEIA
CEPHEUS
Mizar
M51
CANES VENATICI
NGP
COMA BERENICES
M64
DRACO
M31
LACERTA
BOOTES
Arcturus
Deneb
CYGNUS
Vega
LYRA
M13
HERCULES
CORONA BOREALIS
PEGASUS
M57
SERPENS CAPUT
M27
VULPECULA
SAGITTA
M5
VIRGO
Enif
M15
DELPHINUS
Altair
EQUULEUS
OPHIUCHUS
AQUILA
AQUARIUS
LIBRA
M11
SCUTUM
M16
M17
SERPENS CAUDA
CAPRICORNUS
Uranus
Jupiter
M20
M8
PISCIS AUSTRINUS
Antares
M4
SAGITTARIUS
M6
M7
MICROSCOPIUM
LUPUS
CORONA AUSTRALIS
SCORPIUS
GRUS
6231
TELESCOPIUM
INDUS
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
10:00 p.m. on September 1
9:00 p.m. on September 15
8:00 p.m. on September 30

THE PATH OF THE PLANETS


UMa
CVn
Lyn
Aur
Per
Cas
And
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Gem
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Com
Mars
Venus
Path of Moon
Ecliptic
Ori
Tau
CMi
Sun
Sex
Psc
Juno
Mon
Eri
Crt
Hya
Crv
CMa
Lep
For
Sc
Col
Cae
Pup
Phe
Hor
14
13
12
11
10
9
8
7
6
5
4
3
2
1
30
29
28
27

Objects visible before dawn

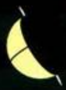
Venus passes 3° south of Mars on September 4

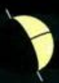
A total lunar eclipse occurs on September 26/27

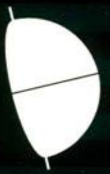
Saturn is at its brightest for 1996

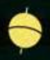
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.



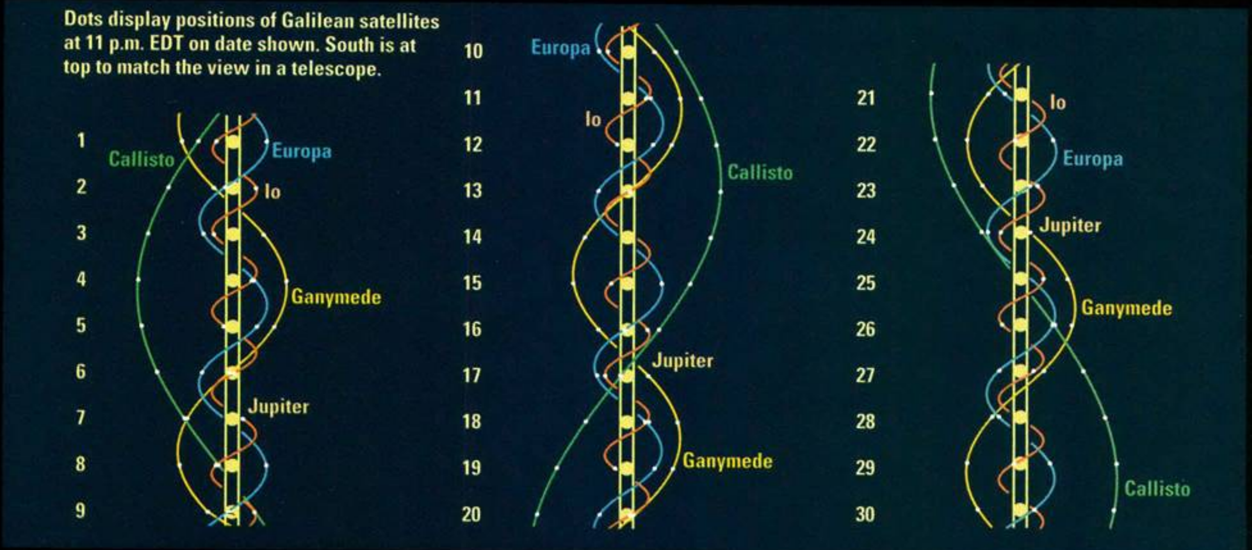




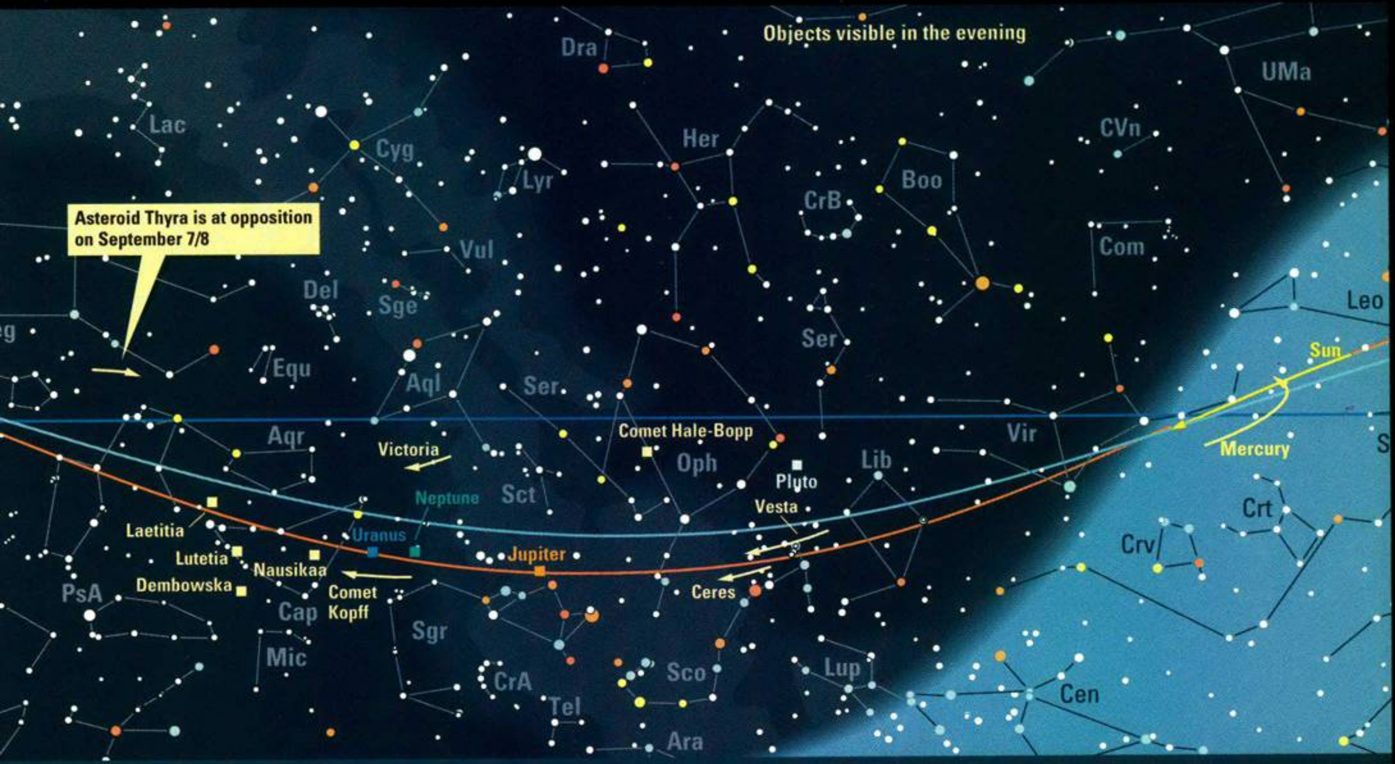


PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	September 1	September 30	September 15	September 15	September 15
Magnitude	0.8	0.1	−4.2	1.5	−2.4
Angular Size	8.8"	7.7"	18.4"	4.6"	40.9"
Illumination	33%	36%	63%	94%	99%
Distance (AU) from Earth	0.766	0.869	0.906	2.042	4.815
Distance (AU) from Sun	0.444	0.309	0.722	1.581	5.177
Right Ascension (2000.0)	12h05.3m	11h24.1m	8h42.4m	8h23.3m	18h35.2m
Declination (2000.0)	−4°36'	4°35'	17°06'	20°24'	−23°24'

JUPITER'S MOONS



Dots display positions of Galilean satellites at 11 p.m. EDT on date shown. South is at top to match the view in a telescope.


Objects visible in the evening
Dra
UMa
Lac
Cyg
Lyr
Her
CVn
Boo
CrB
Com
Vul
Del
Sge
Leo
Ser
Equ
Aql
Ser
Sun
Aqr
Victoria
Comet Hale-Bopp
Oph
Vir
Lib
Pluto
Mercury
Neptune
Sct
Vesta
Crt
Laetitia
Uranus
Jupiter
Crv
Lutetia
Nausikaa
Dembowska
Comet Kopff
Ceres
PsA
Cap
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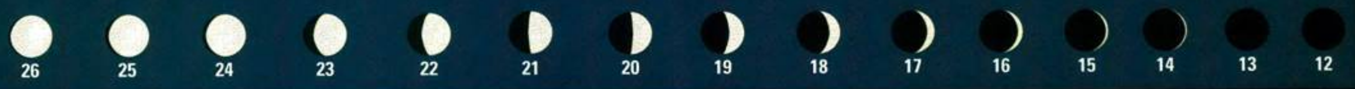
Mic
CrA
Sco
Lup
Tel
Cen
Ara

Asteroid Thyra is at opposition on September 7/8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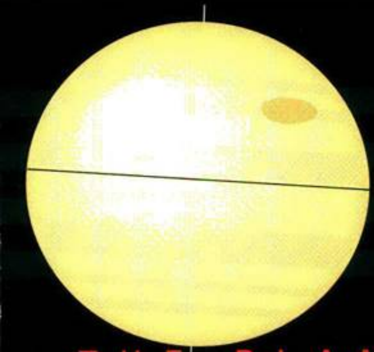
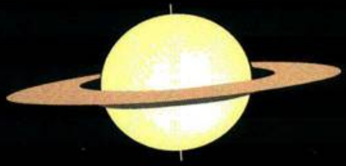
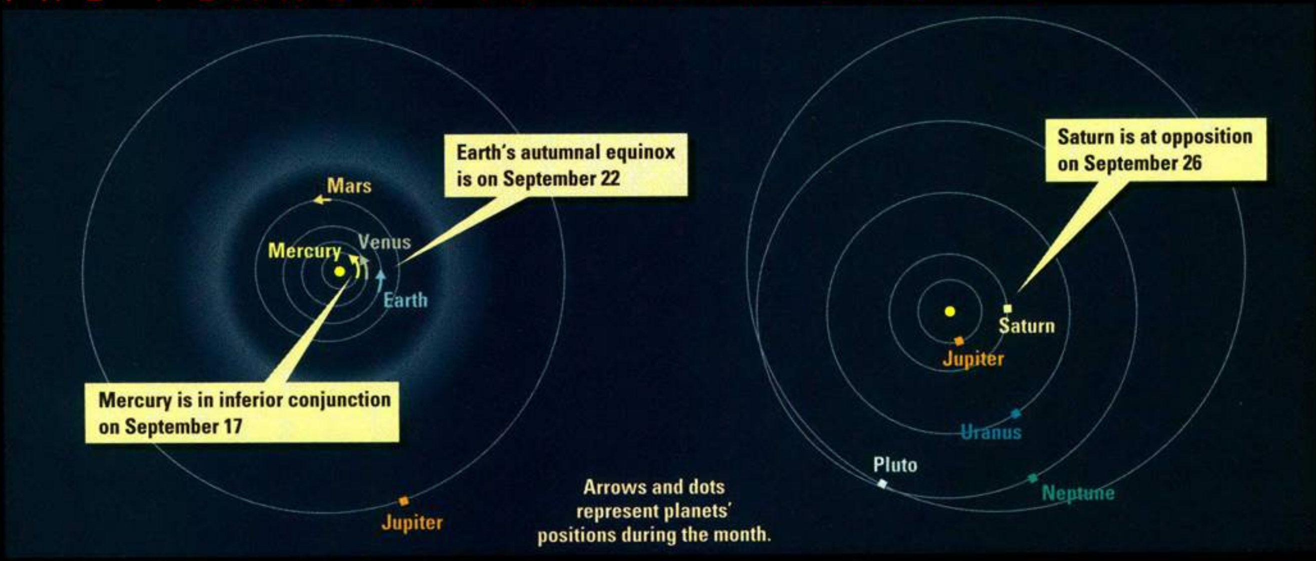




SATURN	URANUS	NEPTUNE	PLUTO
September 15	September 15	September 15	September 15
0.5	5.7	7.9	13.8
19.5"	3.7"	2.3"	0.1"
100%	100%	100%	100%
8.519	19.142	29.604	30.275
9.502	19.783	30.159	29.926
0h22.2m	20h13.2m	19h48.0m	16h04.9m
–0°26'	–20°32'	–20°39'	–7°51'

THE PLANETS IN THEIR ORBITS


Mars
Mercury
Venus
Earth
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Earth's autumnal equinox is on September 22

Mercury is in inferior conjunction on September 17

Saturn is at opposition on September 26

Arrows and dots represent planets' positions during the month.

bends the red component of sunlight across the lunar surface. By 10:54 p.m., the Moon is completely immersed within our planet's dark shadow.

Astronomers rate how dark the Moon is at mid-eclipse by using what's called the Danjon scale. This scale has five levels, from 0 to 4. An estimate of '0' indicates the Moon is so dark it is almost invisible. A gray-brown Moon at mid-totality with few details visible rates a '1' on the scale. A more obvious dark-red color with a brighter rim gets a '2' reading. A '3' goes to a brighter, red-colored eclipse with the Moon easily visible. The top of the scale, '4', gets assigned to a brilliant orange eclipse with many details of the Moon still remaining clearly visible.

Many factors affect the Moon's brightness during eclipses, such as how deep the Moon travels into the shadow and the condition of Earth's atmosphere at the time of totality. If large cloud formations dot Earth's limb or volcanic ash from recent eruptions remain suspended in the atmosphere, the eclipse appears dark.

As if seeing an orange orb suspended east of the Milky Way weren't enough, eclipse night offers two other interesting sights. **Saturn** shines at magnitude 0.5 about 3° south-southeast of the Moon, having reached opposition only four hours before mid-eclipse.

Still opening up from last February's ring plane crossing, the rings of Saturn present a fine display for any telescope. Coincidentally, the Moon passes closest to Saturn for September almost exactly at mid-eclipse.

The big question for this

Plumb Earth's Shadow

The Moon undergoes an eclipse on the evening of September 26 for all the western hemisphere to see. Robbed of bright sunlight by Earth's shadow, the Moon's face transforms into a delightful blend of reddish colors.

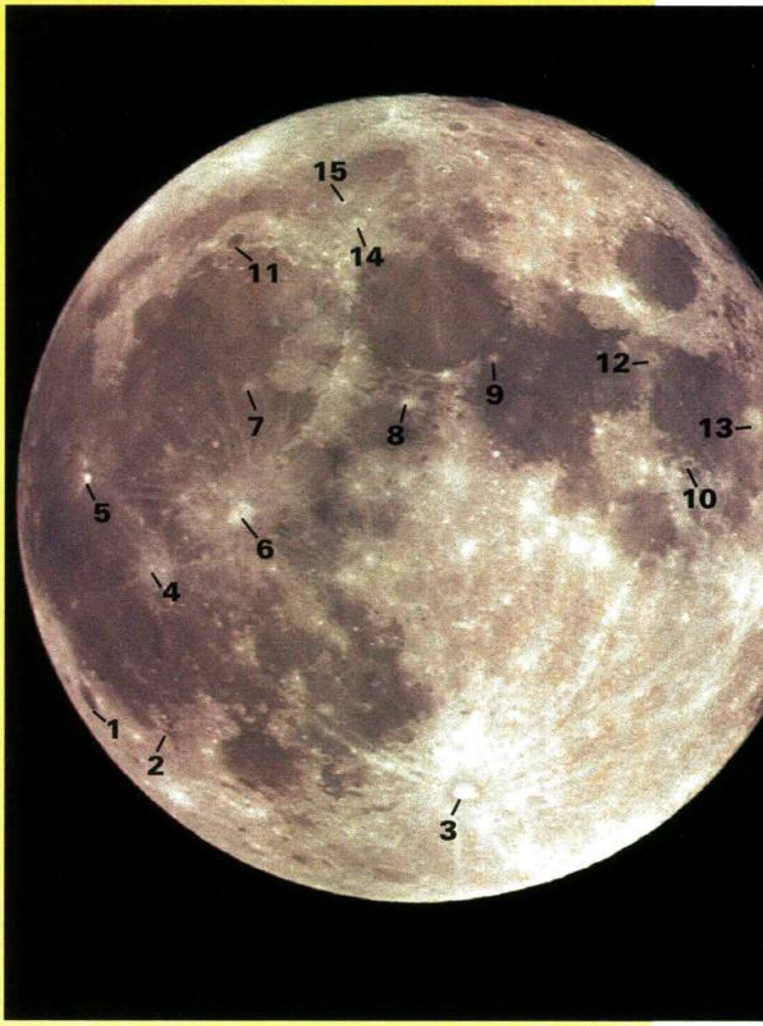
The amount of light that makes it to the Moon during eclipse, not to mention the very shape of Earth's shadow, depends upon clouds over places like Moscow, Saudi Arabia, and Antarctica.

Measure what are likely the effects of weather over these areas by scrutinizing Earth's shadow during the eclipse. Compare the entry and exit times of craters in to and out of Earth's shadow with times listed in the accompanying table. (The times list when the shadow reaches or leaves a crater's center.)

If a feature enters the shadow before a predicted time or exits later, something in the atmosphere along Earth's sunrise/sunset limb, perhaps a weather system, is making our planet's shadow "fatter" than usual.

Conversely, if a crater enters the shadow too soon or exits too early, the umbra might be narrower at that point.

Don't be surprised if crater timings on different areas of the Moon differ wildly from predictions; seldom is Earth's shadow perfectly round. Clouds, aerosols, and dust in the Earth's atmosphere often conspire to make spikes and blobs along the umbra's periphery. — *Alister Ling*



Alan Dyer

Earth's Shadow Creeps Across the Moon

Crater Name	Enters Shadow*	Exits Shadow*
1- Grimaldi	9:17	11:37
2- Billy	9:18	11:37
3- Tycho	9:29	11:44
4- Kepler	9:29	11:46
5- Aristarchus	9:34	11:48
6- Copernicus	9:36	11:50
7- Timocharis	9:46	11:55
8- Manilius	9:51	11:58
9- Plinius	9:57	12:05
10- Goclenius	9:58	12:08
11- Plato	10:00	12:14
12- Taruntius	10:03	12:12
13- Langrenus	10:03	12:22
14- Eudoxus	10:04	12:25
15- Aristoteles	10:07	12:32

* Eastern (EDT) time

Observer's Challenge:
Planetesimals in Capricornus

Every now and then we profile a pair of asteroids that occupy similar spots in the sky. This month it's a trio of asteroids for the taking. All these asteroids lie near 42 Capricorni, a respectable 5.1 magnitude guidepost tucked in the northeast corner of Capricornus, near the Seagoat's border with Aquarius.

39 Lataetia is the brightest of the three this month, starting September at magnitude 9.5 and finishing up at magnitude 9.9.

Along its path, the 159-km-wide minor planet passes a number of stars easily accessible through binoculars. It's extremely close to a field star on the moon-free night of September 12.

Lataetia was found by French astronomers on February 8, 1856, who decided to name their discovery in honor of the Roman goddess of gaiety. Lataetia is 235 million km from Earth this month.

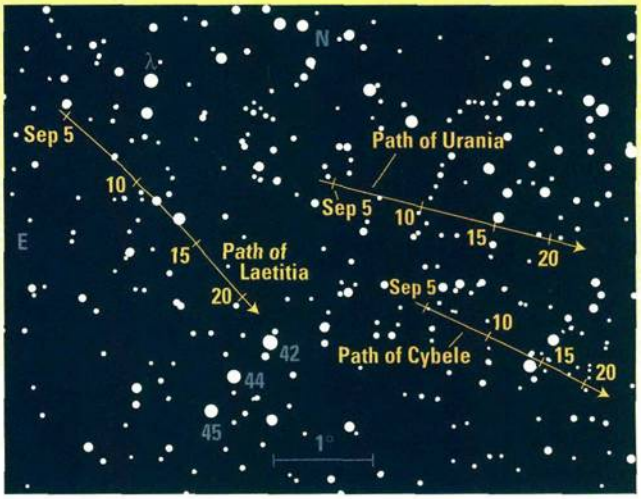
30 Urania — named after the muse of the heavens by British astronomers after its discovery on July 22, 1854 — cruises west of Lataetia, ranging from magnitude 10.3 to magnitude 10.7 as the month progresses. The tiny planetoid measures only 104 km across and lies 190 million km from Earth during September.

To the south and west of Urania, look for 65 Cybele, a bit tougher at magnitude 11.6 (9/1) and 11.9 (9/30).

The 245-km-wide planetoid is a giveaway on September 14 when it scoots away from a wide pair of 9th-magnitude stars.

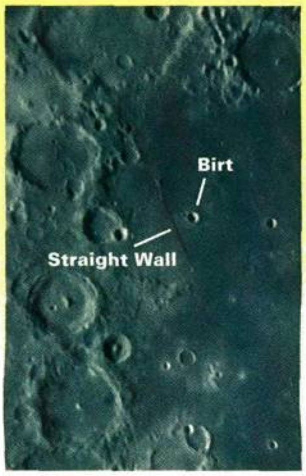
Cybele, the Phrygian name for the Greek goddess Rhea, was first seen at the Marseilles Observatory in France on March 8, 1861, less than five weeks before America plunged into civil war. Its average distance from Earth this month is 350 million km.

An asteroid's motion betrays its nonstellar nature. When bright stars lie close enough to serve as reference points, a handful of hours is all you need to trap your interplanetary quarry. — *A. L.*



First Views:
Pull An All-nighter

There are a number of fascinating events happening on the evening of Friday, September 20, that will keep any avid skywatcher awake all night.



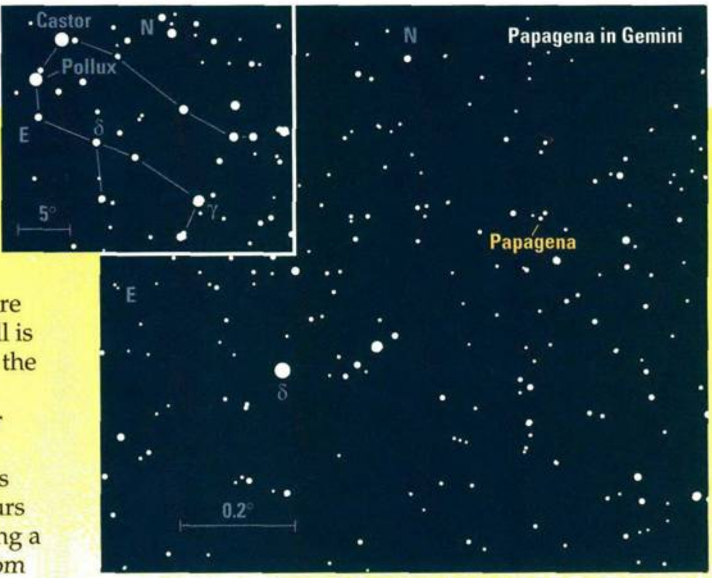
Tony Pacey

First up for attention is one of the most obvious targets in the sky: the First Quarter Moon. A famous feature called the Straight Wall is perfectly placed along the day-night terminator.

This amazing linear feature — actually a slumped fault line — is best seen for a few hours on Friday evening, lying a third of the way up from the Moon's south pole. Find it along the eastern shore of Mare Nubium.

The 240- to 300-meter-high feature, also called Rupes Recta, is 110 km long and averages 2.5 km in width. Look for the crater Birt (17 km wide) and its tiny companion Birt A (6.8 km) immediately to the west.

Watch the wall's razor-thin shadow shorten as the hours tick away.



Next, hop on over to Jupiter, just 6° south of the Moon, to scan its cloudtops. Four Galilean satellites are arranged, respectively, from west to east: Callisto, Io, Europa, eclipse is, will **Comet Hale-Bopp** be visible to the naked eye during totality? As Luna cloaks herself in Earth's shadow, the sky becomes darker and fainter stars pop into view.

Strong moonlight drowns out fainter objects, especially diffuse ones like comets. In the darkness surrounding mid-eclipse, however, magnitude-5.4 Hale-Bopp should be an easy binocular object in the eastern side of Ophiuchus, between Gamma (γ) and Eta (η) Ophiuchi.

Monitor the comet as the eclipse progresses; if Hale-Bopp is brighter than predictions, there is a good chance you could spot it with the naked-eye.

Totality ends when the Moon exits Earth's umbra at 11:29 p.m. EDT. All told, it takes 66 minutes to depart the umbra and another hour to leave the lighter penumbral shadow.

When the Moon finally quits Earth's shadow at 1:36 a.m. EDT, North Americans won't see another eclipse like this one until January 20, 2000.

But September holds one celestial event that happens year after year. The autumnal equinox arrives at 2 p.m. EDT on September 22. At that exact moment our Sun, traveling along the ecliptic, crosses the celestial equator to head south for the winter.

This apparent motion is caused by Earth's polar tilt and its annual trek around our star (see "Tilt-a-Whirl Astronomy," March 1996). The Sun now begins edging southward day by day until it reaches its lowest point on December 21, the first day of winter. If we could eliminate solar glare and blue sky at noon on that day, the Sun would lie barely north of the Lagoon Nebula, M8.

While using the Sun as a deep-sky object marker is a bit of a stretch, one bright evening planet fills that role during September. As twilight turns to night, look south into Sagittarius for brilliant **Jupiter**.

All this month the planet lies near one of the sky's brightest globular clusters, 6th-magnitude M22, which glows across 10,000 light-years of interstellar space. By contrast, Jupiter shines brightly at magnitude –2.4 from only 40 light-minutes away.

On September 3, Jupiter is just 1½ Moon-widths northwest of M22. On September 22 it passes M22 again, this time a half-degree, or a Moon's width, north of the cluster.

After you locate the Jupiter/M22 duo, use binoculars to scan a little east for the remotest of all Messier objects, M75.

This 9th-magnitude globular cluster lies six times M22's distance from Earth, at 60,000 light-years. Periodic Comet Kopff visits M75 this month (see the project box).

Now move 4° west-northwest of M75 to find **Neptune** shining at magnitude +7.9. Neptune, currently the farthest planet from the Sun, was discovered exactly 150 years ago on September 23, 1846 (see "Neptune's Discovery 150 Years Later," page 42).

This bluish planet lies so far away at 2.8 billion miles that it only displays a 2" disk when viewed from Earth. If you can't find Neptune in binoculars, try using a rich-field telescope.

While you're on the trail of gas giant planets, scan for **Uranus** in Capricornus the Seagoat. This month it lingers about 2° northeast of M75, not far from Comet Kopff. This magnitude-5.7 planet is easy in binoculars; can you see it with the naked eye?

Even though Uranus is practically a twin to Neptune, Uranus lies a billion miles closer to us. This lets it shine brighter and present a disk almost 4" wide to viewers on Earth, easily seen in any backyard telescope.

The mother of all signposts, a 10-day-old Moon, passes 4° north of Uranus on September 22.

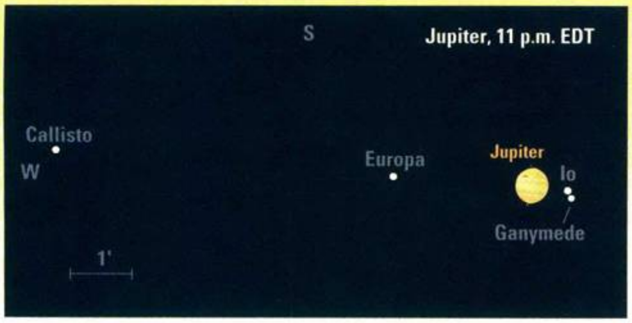
After catching Jupiter, Neptune, and Uranus in the evening sky, our next planet, **Mars**, rises about

and Ganymede. Check back on their positions before Jupiter gets too low after midnight.

Once the Moon has set at 1:30 a.m., it's time to move on to Comet Kopff and the asteroids noted in other project boxes.

Speaking of asteroids, magnitude-11.4 Papagena skims 30' — a lunar diameter — to the west-northwest of Delta (δ) Geminorum tonight. Use the accompanying star map to hop from Delta to the starlike asteroid.

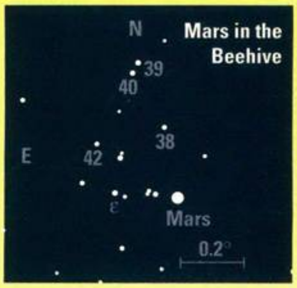
Papagena was discovered on June 7, 1901 at the Heidelberg Observatory in Germany, and was named after a character in Mozart's opera 'The Magic Flute."



Tonight's highlight actually comes in the early hours of Saturday morning. That's when Mars cruises through the heart of M44, the Beehive star cluster in Cancer.

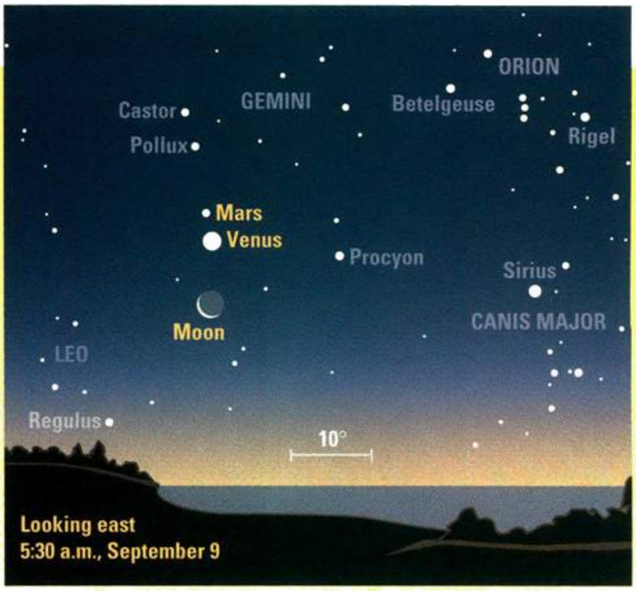
Astronomers place the cluster's 200 stars at 525 light-years away, which contrasts with Mars' close distance of 17 light-minutes. Naturally orangey-red Mars will be considerably brighter than the cluster stars.

The icing to this nighttime cake is watching dawn swallow up the stars of approaching winter one by one.



Before that, though, look for the soft pyramidal glow of the zodiacal light arcing up through Mars just before the blue light of dawn appears. This ethereal glow is sunlight reflecting off of interplanetary dust along the plane of the solar system. — *A. L.*

Morning's Celestial Necklace



Looking east
5:30 a.m., September 9

Straight lines are an unusual sight in the night sky, much less one that shows the ecliptic, the path the planets follow through the heavens.

On the morning of September 9 a line that closely mirrors the ecliptic extends from Castor and Pollux through Mars and Venus. The waning crescent Moon is just out of step for North Americans, but is right in the chorus line for European and African observers.

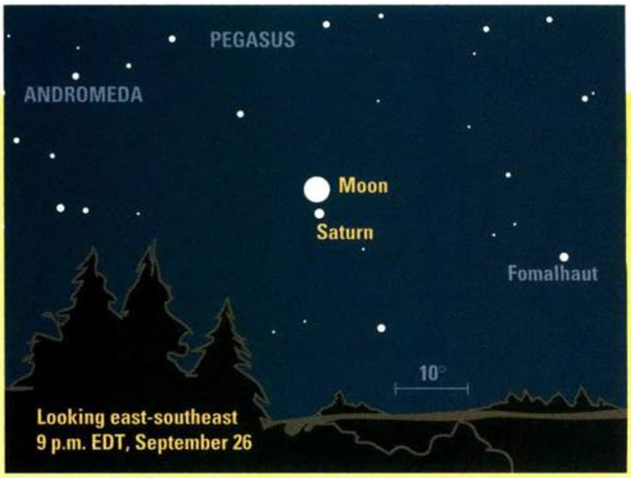
The morning line-up provides a chance to visualize the depth of space and glimpse its color.

Our nearby Moon shines at a bright magnitude –7.7 from 1.3 light-seconds away. It's only bright because of proximity, for lunar soils are for the most part asphalt-dark.

From a distance of seven light-minutes, Venus blazes at magnitude –4.2 due to its cloak of white clouds. Mars' ruddy soils reflect considerably more light than the Moon, but the planet's small size and great distance — 17.3 light-minutes — leave it glowing at only magnitude-1.4.

Taking the giant leap into interstellar space we reach peach-colored Pollux. How similar in color do you think the star looks to Mars? Unlike Mars, this nightlight shines under its own power with the same apparent brightness, but lies 35 light-years beyond Mars. White Castor glows above Pollux at magnitude 1.9 from a distance of 49 light-years. — *A. L.*

Saturn Rings In Opposition



Looking east-southeast
9 p.m. EDT, September 26

It's time once again for sidewalk astronomers to show off the crown jewel of our solar system.

Saturn reaches opposition on Thursday evening, September 26, along with an eclipsed Moon. On that evening the Ringed Planet stays up the entire night, rising at sunset and setting near sunrise. After last year's ring crossings, Saturn will again draw gasps from passersby, its rings inclined a respectable 5°.

Cassini's division, the main gap between the bright B ring and outer fainter A ring, is visible in any 6-inch scope where the rings are farthest from the disk.

Take time to note the subtle shades and brightness differences within the ring system. As the Voyager spacecraft showed us, what appears as a solid ring through Earthbound telescopes is actually thousands of ringlets, each composed of chunks of rock and ice hardly larger than good-sized boulders.

At the start of the month, Saturn's shadow on the ring lends a 3-D feel. The shadow shrinks as we progress toward opposition on September 26, when the Sun, Earth, and Saturn line up so no shadow is visible.

Throughout autumn, Saturn's 0.9-magnitude peach-colored glow stands alone in the empty sky beneath the Great Square of Pegasus. Wait a couple of hours for the planet to gain some altitude so the sight of its delicate rings will not be ruined by turbulence in the evening air. — *A. L.*

Charles Capen

Autumn's Harvest of Comets

Two notable comets, summer's fading Kopff and next spring's brightening Hale-Bopp, grace the evening sky after twilight ends this month.

First, take advantage of moon-free skies during the first half of September to spot Hale-Bopp in binoculars and with the unaided eye. Look for it in western Ophiuchus, a few degrees south and slightly west of the magnitude-7.6 globular cluster M14.

Binoculars might reveal a fan or a tail, while to the naked eye it will merely look like a swatch of light along summer's Milky Way. A telescope will show fine detail in the coma. Later this month, look nearby for NGC 6366, a 10th-magnitude globular cluster.

Meanwhile, Periodic Comet Kopff continues to put on a decent show for backyard observers this month in the western reaches of Sagittarius.

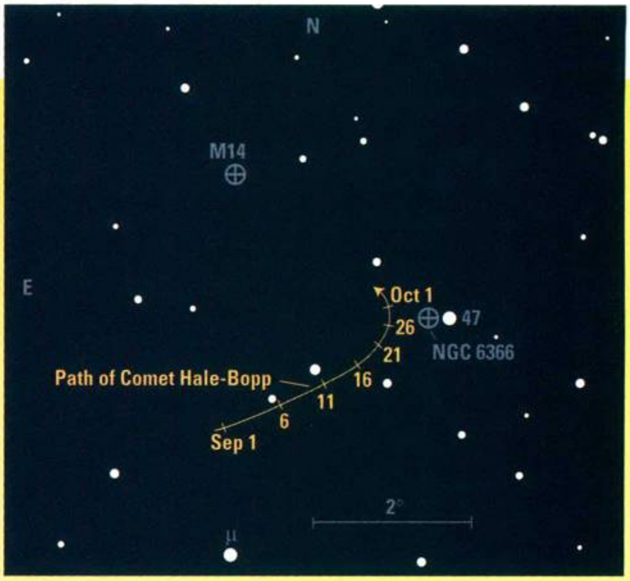
September sees the 9th-magnitude fuzzball outbound and fading slowly after a July close approach to the Sun.

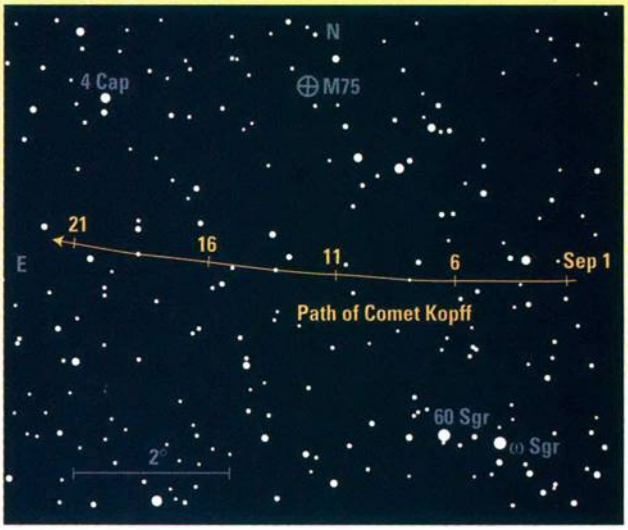
Beginners drawn in by Hyakutake have a chance to see a more typical comet in Comet Kopff.

The icy snowball swings into the inner solar system every 6.4 years. Even though Kopff is slated to return in 2002, that visit's unfavorable viewing geometry means we won't have another good look at it until the summer of 2009.

Your best chance to see Kopff comes early in the month when the Moon is out of our sky and Sagittarius hasn't sunk too low in the southwest after evening twilight ends.

Look for it south of the magnitude-8.5 globular cluster M75, just west of the Capricornus/Sagittarius border. Kopff makes an attractive pairing with M75 as it slowly slides 3° south of the globular on September 12. — *A. L.*





two hours after midnight in Cancer the Crab.

While you wait for it to clear haze near the horizon, watch our Galaxy gently turn above your head. The Milky Way started tonight as the sky's north-south spine. Slowly, in a majestic pirouette, the misty-looking band orients itself east-west as early morning approaches. The real reason for this is that we are turning beneath all this grandeur.

By 4 a.m. Cancer is well up in the east along with ruddy Mars. All this month the Red Planet intrudes upon another Messier object, M44.

Binoculars reveal numerous stars in M44 that resemble bees buzzing around a hive, hence the cluster's popular moniker the Beehive.

On September 21 Mars lies 0.5° south-southwest of the Beehive cluster, its ruddy appearance providing a nice contrast to the fluttering starlight nearby.

Telescopically, Mars remains rather small, presenting a rather underwhelming disk of 4". (During favorable oppositions, like the one coming up in 2003, Mars swells to an impressive 26".)

Shortly before dawn, Mars gets joined by **Venus** and, early in the month, a crescent Moon. On September 4 Venus lies 2.9° south of Mars, which seems pale at magnitude 1.5 when compared to Venus's dazzling magnitude of –4.5.

Venus betrays itself through a telescope as a growing gibbous phase, currently 60% illuminated. A beautiful waning crescent Moon slides beneath the two planets on September 8 and 9 (see the project box).

Before sunrise rounds out the night's observing, catch Regulus climbing very low in the east during twilight in Leo the Lion.

Look south for winter luminaries such as Rigel and Betelgeuse in Orion, and Sirius in Canis Major. Eventually, twilight will win over these brilliant icons of winter.

Within a few hours, the warmth of an autumnal Sun puts a temporary halt to the advancing cool air of fall, for now at least. Could it be winter's just around the corner? □

Martin Ratcliffe directs the Henry Buhl, Jr. Planetarium in Pittsburgh, Pennsylvania. Alister Ling works as a meteorologist for Environment Canada.

Eclipse at Harvest Moon

A large orange ball will rise in the east, turn white, then disappear into a deep red shadow — the last total lunar eclipse for North Americans until 2000.

by Alan Dyer

Get ready for a wonderful eclipse. On the night of September 26/27, the Full Moon will slide through the dark shadow of our planet. For an hour and ten minutes, the only light hitting the Moon will be the reddish glow from all of Earth's sunrises and sunsets.

This is a total eclipse of the Moon, the second of 1996. But unlike the April 3/4 event, which favored the eastern United States and Canada, this eclipse can be seen from almost all of North America during convenient evening hours. Elsewhere in the Western Hemisphere, all of South America sees the complete eclipse during the hours around local midnight. Farther east around the curvature of Earth, residents of Western Europe and much of Africa, with memories of April's eclipse still fresh, are treated to another in the predawn sky.

Unusual Harvest

As with all lunar eclipses, this one occurs precisely at Full Moon, when the Moon lies opposite the Sun near Earth's shadow in space. Of course if that's all it took, we'd have a lunar eclipse every month. In most months, however, the tilt of the Moon's orbit carries the Full Moon anywhere up to 5° above or below our planet's 1½°-wide umbral shadow. But twice a year, in "eclipse seasons" separated by a few days shy of six months, the Full Moon must pass through some part of our shadow.

The bonus of this eclipse is that it occurs at September's Full Moon — the Harvest Moon — probably the most widely observed Full Moon of the year. The Harvest Moon rises a little before 7 p.m. daylight time, just when people are out enjoying the fall evening. It also rises due east, so anyone traveling in that direction sees it looming ahead of them like a giant pumpkin at the end of the road.

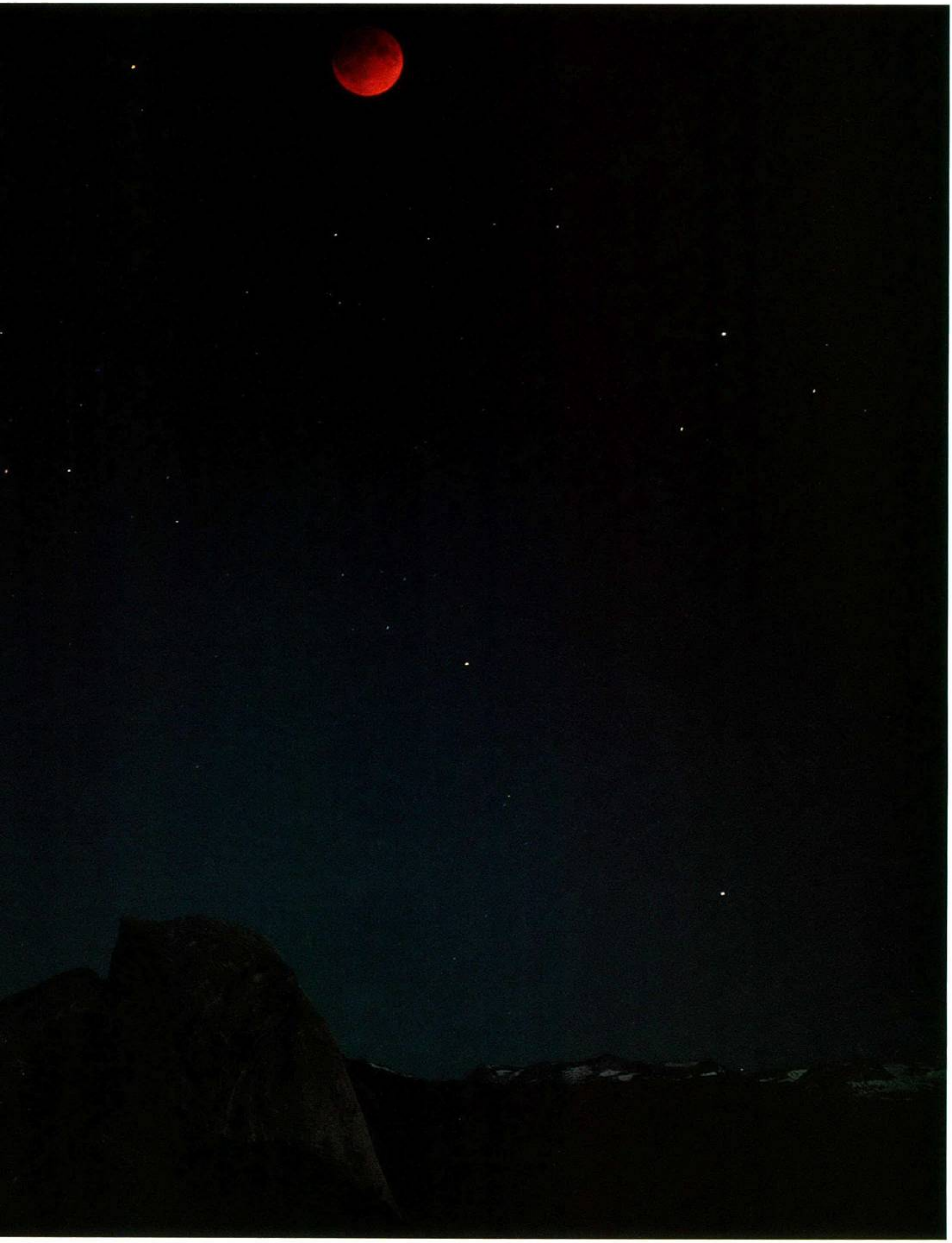
And it does look like a pumpkin — the rising Harvest Moon often appears a golden yellow. Our atmosphere creates the tint by filtering out the short blue wavelengths of moonlight and allowing only the yellows and reds to reach our eyes. Once the Moon climbs well above the horizon, its disk turns white and lights up the autumn landscape, helping farmers bring in the harvest.

But on this Harvest Moon night, at least for North Americans, nature will turn off the Moon for over an hour beginning one to four hours after moonrise.

The striking attraction of any total lunar eclipse is the color. Immerse the Moon in Earth's shadow and it would stand to reason that the Moon would go dark. Very dark. After all, no sunlight can reach it because Earth stands in the way.

If Earth were an airless planet, that's exactly what would happen. The eclipsed Moon would vanish into a pitch black earthly shadow.

A pretty foreground can help create a stunning portrait. Tom Bullock captured the eclipsed Moon among the stars of Sagittarius on July 6, 1982.



Instead, the Moon turns red. It's our atmosphere at work, acting like a filtered lens, bending red light into our planet's shadow while scattering out the shorter blue wavelengths that color our daytime sky. What's left creates a crimson-colored eclipsed Moon.

The leisurely pace of a lunar eclipse leaves plenty of time for both looking and photography.

But every eclipse is unique. If our atmosphere is choked with high-altitude volcanic dust, even the red light can't make it through. Total eclipses following the 1991 eruption of Mt. Pinatubo were so dark it was hard to see the Moon with the naked eye. But by 1993, the air had cleared noticeably and the totally eclipsed Moon once again appeared a striking red.

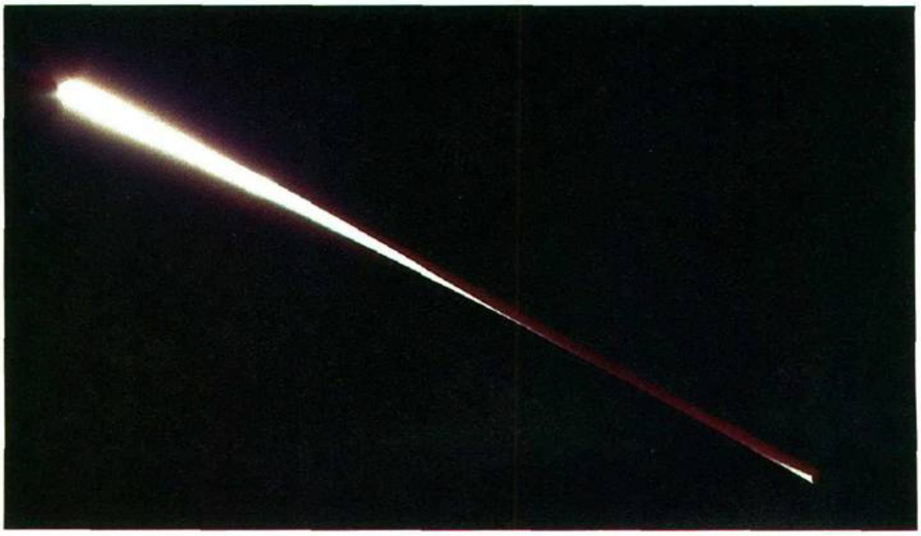
Although the red glow gets all the attention, other subtle tints are worth watching for. During the partial phases, check out the shadow's fuzzy edge. Pastel yellows, blues, and even greens have been sighted rimming the shadow at previous eclipses, elusive tints that are tough to capture on film. Binoculars often show them best, or a telescope working at no more than 20 to 30 power.

Another effect to note during totality is how even Earth's shadow appears across the Moon's disk. This is not a symmetrical eclipse — the Moon passes north of the shadow's center. At mid-totality, the southern limb of the Moon will likely be darkest because it's closer to the shadow's dark core. The northern limb lies nearer the shadow's edge and should appear brighter and more vivid. Even so, massive banks of clouds around Earth's limb can project dark patches onto the Moon's eclipsed face. With all these possible variations, no one can forecast what this or any total eclipse will look like. That's part of the fun of watching.

Making Contact

But we can predict exactly when the eclipse will occur. The Moon first touches Earth's shadow at 8:12 p.m. Eastern Daylight Time on Thursday, September 26. From most of Mexico and from American states and Canadian provinces west of about longitude 99° W, the Moon won't have risen yet. Don't worry, you're not missing anything. During the first hour the Moon moves through the light penumbral shadow, whose darkening effect can barely be noticed.

The eclipse really gets underway at 9:12 p.m. EDT (8:12 CDT, 7:12 MDT, 6:12 PDT) when the umbral shadow takes a small, dark bite out of the left edge of the Moon. For the next hour and seven minutes of partial eclipse, the darkness engulfs more of the Moon's disk as it slides inexorably into the shadow.



A single long exposure can record the diminishing light of the partial phases as well as the darkness of totality. Glenn Lambert took this photo of the September 6, 1979, event by leaving open the shutter of a 50mm f/16 lens for 120 minutes.

If you live around longitude 114° W, the partial phase begins just as the Harvest Moon rises. From sites farther west, the Moon rises during the partial phase.

The partial eclipse ends and totality begins at 10:19 p.m. EDT, when the Moon slides completely within the umbra. A bright rim remains on the right edge of the Moon. By this time, the Moon has risen from all locations in North America except the Yukon and Alaska. From there, the Moon rises during totality.

The total phase lasts 70 minutes, with mideclipse (when the Moon looks darkest) occurring at 10:54 p.m. EDT. Although this is plenty of time to take in the view and snap some photos, it's surprising how fast an hour of totality can pass. At 11:29 p.m. EDT, a bright rim appears on the left edge of the Moon as it begins to emerge from the umbra. Totality is over.

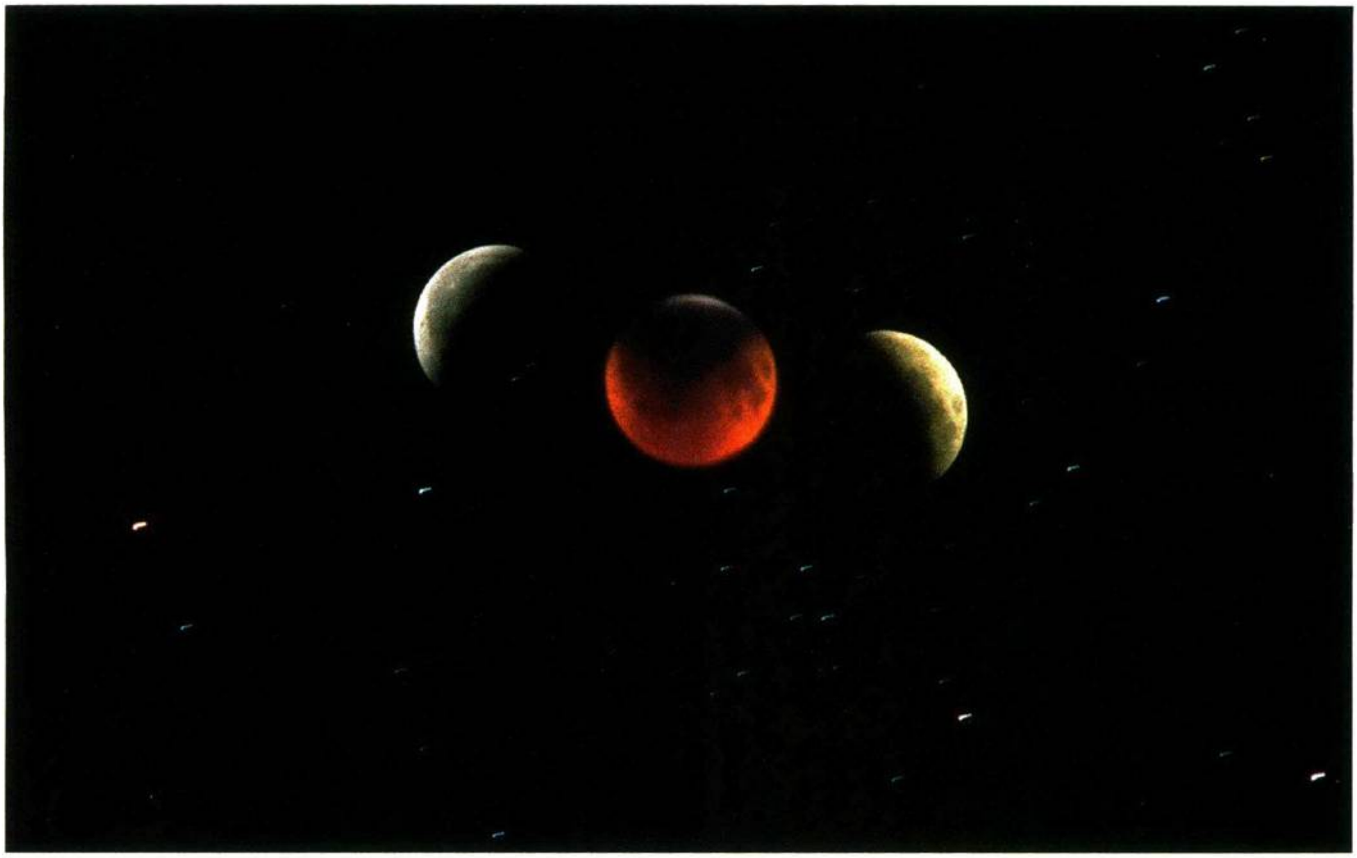
For the next hour and seven minutes, the initial partial phase repeats in reverse. The Moon creeps out of the shadow until 12:36 a.m. EDT, when it finally clears the umbra. During this final partial phase, the Moon rises from western Alaska and Hawaii. They miss seeing any portion of totality.

Five hours and 24 minutes after it first touched the penumbra, the Moon ends its shadow encounter, with last penumbral contact at 1:36 a.m. EDT.

Moon Shots

The leisurely pace of a lunar eclipse leaves time for both looking and photography. Even if you have no more than a camera on a tripod, several photo opportunities present themselves.

With a 50mm lens under a dark sky, try exposures of ½ to 20 sec-



The Moon outlines Earth's shadow on December 9, 1992. Benjamin Gomes-Casseres shot the eclipse with a 200mm lens on ISO 400 film using ½-second exposures at f/64 for the partial phases and a 5-minute exposure at f/8 for totality.

onds at f/2.8 to f/4 using ISO 400 to 800 film. These may overexpose the eclipsed Moon, but will pick up neighboring stars and record them as points. To capture the partially eclipsed Moon rising during twilight, try metering exposures off the surrounding sky.

For a closer view, switch to a 135mm to 200mm telephoto. Stay with fast film but keep exposures shorter than 2 to 3 seconds, even during totality. This will prevent background stars and the Moon itself from trailing. The shorter exposures will limit how many stars the film will record, but a telephoto will nicely frame the Moon above the brightest nearby object — Saturn, sitting photogenically just 2° below the Moon.

A creative variation is to purposely let the Moon trail across the film, not just for a few seconds but for the entire eclipse. A 28mm lens will take in the entire 3½-hour trail from the start of the partial umbral phase, through totality, to the end of the partial eclipse. A 50mm lens can record a two-hour-long eclipse trail.

To prevent ambient light fogging the film, stop the lens down to f/16 or f/22 and use film no faster than ISO 100. A location away from city lights is also best. Photographers in North America should orient the camera parallel to the horizon and place the Moon at the bottom left corner of the frame. The motion of the sky will streak it across the frame, taking it to the top right corner of the frame by eclipse end.

An embellishment is to cover the lens for ten minutes just prior to mideclipse. Open up the lens to f/2.8 or so, then uncover the lens for about 10 seconds. Cover the lens again, then stop the lens down to the same small aperture used for the first half of the trail. After another gap of ten minutes, uncover the lens until the end of the eclipse. The result is a trail broken in the middle by a single image of totality — a surefire hit at the next astronomy club meeting.

During such a long exposure, dew or frost might form on the lens. Don't shine a light at the lens to check it! Instead, watch for dew forming on other exposed glass surfaces. Heater coils will ward off dew, as will an occasional blast from a carefully aimed hair dryer.

A more demanding technique is to take many short shots on one frame. This requires a camera capable of multiple exposures. The rotation of the sky carries the Moon its own diameter in two minutes, so each exposure should be no less than five minutes apart. Ten to 15 minutes is a good choice. Use ISO 100 film and start with an exposure of 1/500 second at f/8 during the penumbral phase. As the Moon digs ¼, ½, and ¾ of the way into the umbral shadow, adjust your exposures to 1/60, 1/30, and 1/15 second, respectively.

Westerners will have a challenge capturing the entire eclipse this way because the Moon will be embedded in deepening twilight for the first hour or so. Each exposure in twilight must be sufficiently underexposed so that the combined effect won't wash out the sky and wipe out later images of the Moon in totality. Taking six twilight shots 10 minutes apart and underexposing each by about three f/stops should do the trick.

This is the last total eclipse of the Moon visible from North America for four years.

Staying On Track

For an eclipse closeup, turn to a telescope. To determine how large the Moon will be on film, divide the focal length of the telescope (in mm) by 110. A 2,000mm-focal-length telescope produces a frame-filling lunar disk 18mm across.

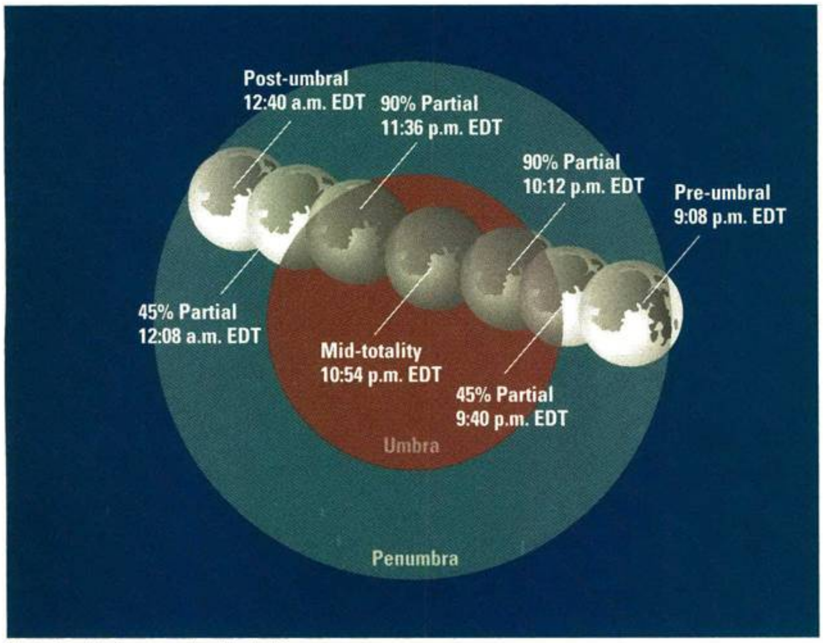
Shooting portraits of totality through a typical f/6 to f/11 telescope requires ISO 400 to 800 film and exposures of 4 seconds to 1 minute, depending on how dark this eclipse is. Even at the short end of the scale, the Moon will trail into a blurry blob unless the telescope has a clock-driven, equatorial mount. Ideally, the drive should be running at the lunar tracking rate, not the sidereal rate. This slower rate follows the Moon more accurately, yielding slightly trailed background stars (if any show up) but a sharper lunar disk.

Another tip for sharp shots is to use the hat trick — hold a dark card over the front of the telescope, open the camera's shutter on Bulb, then make the exposure by flipping the card away and back. It's crude but eliminates all vibration induced by the whack of the camera's shutter and mirror.

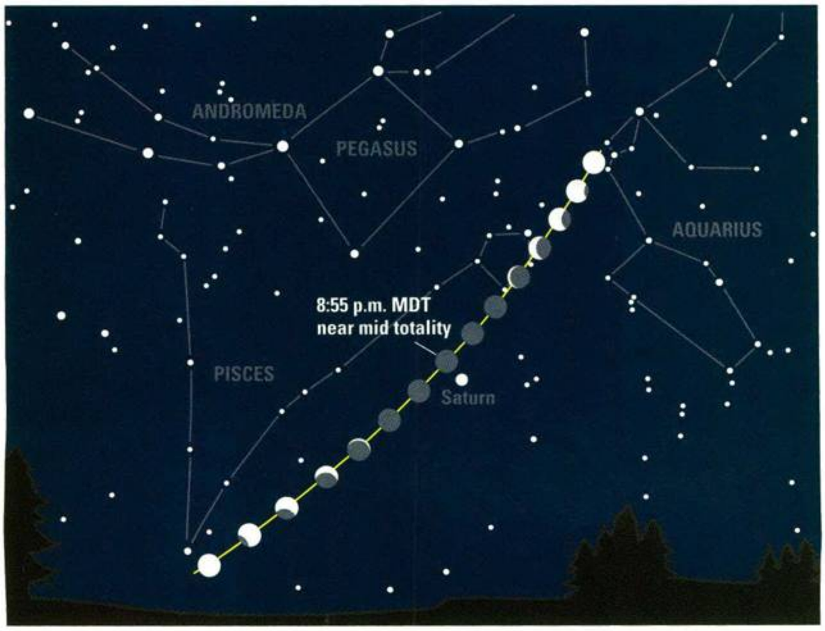
Equatorial telescopes can also be used as tracking platforms for piggybacked cameras. A 200mm to 500mm telephoto will frame the Moon, Saturn, and surrounding stars nicely. But unlike a simple tripod setup, exposures with a tracked camera on ISO 100 to 400 film can extend for several minutes under a dark sky. At mid-totality, this will capture the Moon as a glowing red object floating amid the faint stars of Pisces.

Ambitious photographers with a 400- to 600mm-focal-length telephoto or telescope can attempt what is arguably the most difficult but most striking lunar eclipse portrait. A multiple exposure on one frame can record both the Moon moving in stages through the shadow and the shape of the shadow itself.

Here's what to do. Place the Moon at the right (west) side of the frame near the start of the partial eclipse. Keep the drive run-



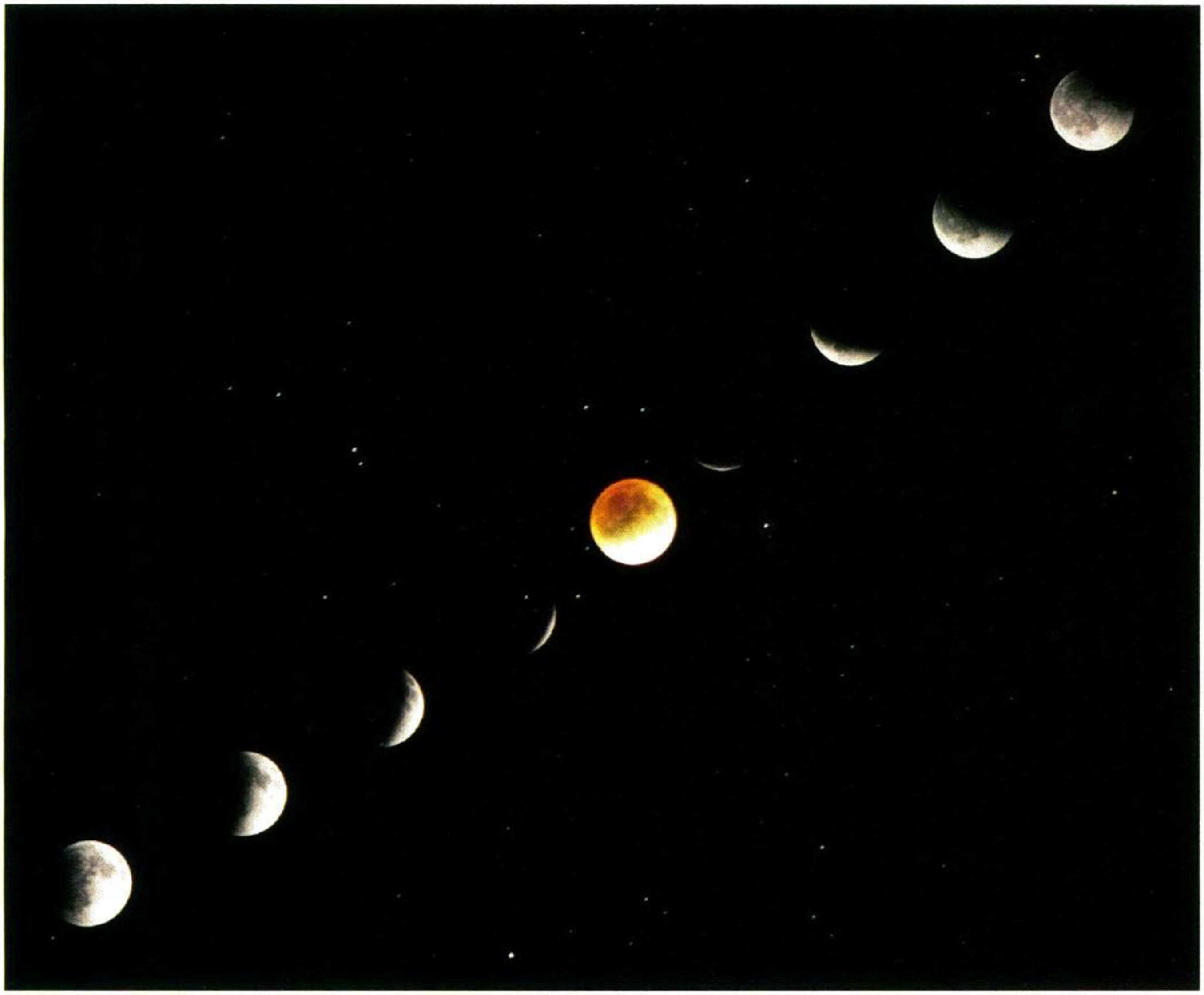
Illustrations by Astronomy: Lee Vande Visse



Two sets of equally spaced exposures bookending one shot of totality will show Earth's shadow dramatically (above, left). See text for details on taking this demanding shot. Exposures every 15 minutes will capture the entire eclipse with a stationary camera and a 28mm lens (left). From eastern and central North America, place the Moon in the lower left corner for the first exposure. From the mountain states, use the diagram as a guide. (Stars are shown for midtotality at 40° N latitude, 110° W longitude.)

ning at the sidereal, not lunar, rate. The Moon's own motion will carry it from right to left (west to northeast) through the shadow and across the frame.

Without advancing the film, take three equally spaced exposures prior to totality: one at 9:08 p.m. EDT (just before the start of partial umbral phase), the second at 45% partial (9:40 p.m. EDT), and a third at 90% (10:12 p.m. EDT). Expose the partial eclipse shots for the bright portion of the disk. Then at midtotality (10:54 p.m. EDT), take one long shot. Complete the composite by taking a mirror-image set of three exposures (at 11:36 p.m., 12:08 a.m., and 12:40 a.m. EDT) during the final partial phase. The partial Moons will overlap but will dramatically outline Earth's shadow. (From the far west, twilight will rule out this type of shot except for the last half of the eclipse.)



David Silverstein squeezed most of the November 28/29, 1993, lunar eclipse on one frame. He used a 175mm lens and exposures ranging from 1/125 second for the first and last partial phase to 2 minutes for totality on Fuji Super G 400 film.

Looking Forward

Technically, this is the last total eclipse of the Moon visible from North America for four years. The next doesn't arrive until January 21, 2000.

However, the eclipse drought is not as bad as it seems. On March 23, 1997, the Moon plunges back through Earth's shadow for a 92% partial eclipse. This is a deep enough passage that the reddening of the shadowed portion of the disk should be obvious.

Although the March '97 event is not total, it comes with a unique bonus — Comet Hale-Bopp is at its peak and lies only 5° above the Andromeda Galaxy. For observers at northern latitudes (45° or higher) the comet-galaxy duo will be 10° to 20° up in the northwest at mideclipse. With the eclipse dimming the Full Moon for an hour or so, comet trackers should be able to grab unique views and photographs of Hale-Bopp.

But that's six months and one eclipse season away. This season we have what promises to be a comfortable, convenient, and spectacular eclipse at Harvest Moon. □

Alan Dyer is a science writer and multimedia producer at the Calgary Science Centre in Alberta, Canada.

Faint Balls of Fire

Tracking distant globulars is not for the faint of heart. To play this game, you'll need black skies, patience, and a big scope.

by David Higgins

Globular clusters —massed spheres of a million stars — swarm around the Milky Way Galaxy like bees around a gigantic flowering blossom. Finding a bright one like M13 in Hercules is a challenge beginners overcome quickly. Some even stumble on M13 by accident.

But you can't find a Terzan or a Palomar cluster by accident. You have to want to find globulars from these catalogs, and pretty badly. Many of those I've followed are slightly brighter than the background sky, and are challenging on less-than-perfect nights with my 25-inch f/5 reflector. Nonetheless, some of them are visible in smaller scopes, offering tests for 10-inch or 12-inch reflectors.

These clusters come from two specialized catalogs hard to locate outside of observatory libraries. The first, the Palomar Catalog, was created by astronomers at Palomar Observatory in the 1950s as they uncovered new clusters during the Palomar Sky Survey. The second, the Terzan Catalog, arose from infrared studies by the French astronomer Agop Terzan at the Observatoire de Lyon. Thankfully, Palomar, Terzan, and other faint globular clusters are plotted on Uranometria 2000.0, making them much easier to find.

Preston Scott Justis

Palomar 10 in Sagitta

Most of the Palomar and Terzan clusters hang low in the summer evening sky in the constellations Scorpius and Sagittarius, roughly toward the bulge of the galaxy. They therefore add a new dimension to midsummer observing. Two rise late in the summer in the constellations Capricornus and Pegasus, and three others can be found in the winter and spring skies, in Auriga, Ursa Major, and Hercules.

To start a summertime tour of these clusters, target **Terzan 3**, one of a collection of faint globulars in Scorpius, slightly more than 1° southwest of N Scorpii. Don't be deceived by the magnitudes of these objects: 12th magnitude may suggest a relatively easy target for big backyard scopes, but this object appears like a tiny, out-of-focus field star. This object is so poorly studied its distance is not known. Moving eastward through Scorpius brings into view **Terzan 12** (NGC 6256), a magnitude 11.2 object lying 33,000 light-years away. Look 2° northwest of Mu (μ) Scorpii and spot a patch of haze with a grainy appearance at very high power.

Martin C. Germano

Palomar 13 in Pegasus

Terzan 2, about 1° south of 45 Ophiuchi, is another challenge globular in Scorpius. This 14th-magnitude haze is a relative neighbor at 7,000 light-years, but the cluster is extremely reddened, making spotting it difficult. Note the 11th-magnitude foreground star floating inside the cluster. Just 2° to the east lies Terzan 1, an extreme challenge. This 16th-magnitude fuzz appears at one end of a string of faint stars aligned northwest-southeast. It lies at the relatively close distance of 19,000 light-years but is blocked by interstellar dust.

Two more Terzan globulars reside in Scorpius. Terzan 4 lies about 1° southeast of Terzan 2, near the large, dim nebula Sharpless 2–13. This is another cluster that requires patience, dark skies, and a whopper scope. It is so poorly studied that its brightness and angular size are not known. Somewhat easier is Terzan 6, found about 3° northeast of the bright open cluster M6. Terzan 6, brighter than 14th magnitude and spanning 1.2', is a reddened cluster lying a mere 9,500 light-years away.

Having finished Scorpius, it's time to move onto the main highway of the Milky Way, crowded

Challenging Backyard Globulars

Name	R.A. (2000.0)	Dec.	Mag.	Size	Dist.	Con.
Palomar 2	4h46.1m	31°23'	13	1.9'	72,000 ly	Aur
Palomar 4	11h29.3m	28°58'	14.2	2.1'	305,000 ly	UMa
Palomar 14	16h11.1m	14°57'	14.8	2.1'	250,000 ly	Her
Terzan 3	16h28.7m	–35°22'	12	—	—	Sco
Terzan 12	16h59.5m	–37°07'	11.2	—	33,000 ly	Sco
Palomar 15	16h59.9m	–0°32'	14.2	4.2'	230,000 ly	Oph
Terzan 2	17h27.5m	–30°48'	14.2	1.5'	7,000 ly	Sco
Terzan 4	17h30.6m	–31°35'	—	—	55,000 ly	Sco
Terzan 1	17h35.8m	–30°28'	15.9	2.8'	19,000 ly	Sco
Palomar 6	17h43.7m	–26°13'	13.6	7.2'	9,500 ly	Oph
Terzan 5	17h48.1m	–24°47'	13.5	2.1'	50,000 ly	Sgr
Terzan 6	17h50.7m	–31°17'	13.8	1.2'	5,000 ly	Sco
Terzan 9	18h01.8m	–26°52'	16	—	48,000 ly	Sgr
Terzan 10	18h03.6m	–26°05'	14.9	—	22,000 ly	Sgr
Palomar 7	18h10.7m	–7°12'	—	7.1'	42,000 ly	Ser
Terzan 11	18h12.6m	–22°45'	16.4	3.2'	80,000 ly	Sgr
Palomar 8	18h41.5m	–19°49'	11.2	4.7'	100,000 ly	Sgr
Palomar 9	18h55.1m	–22°42'	9.2	3.9'	50,000 ly	Sgr
Terzan 7	19h17.7m	–34°40'	—	—	120,000 ly	Sgr
Palomar 10	19h18.2m	18°34'	13.2	3.5'	30,000 ly	Sge
Terzan 8	19h41.7m	–34°00'	12.4	—	75,000 ly	Sgr
Palomar 11	19h45.3m	–8°02'	9.8	3.2'	36,000 ly	Aql
Palomar 12	21h46.5m	–21°14'	11.7	2.9'	60,000 ly	Cap
Palomar 13	23h06.7m	12°46'	14.5	1.8'	80,000 ly	Peg

This table provides **right ascension** and **declination** in epoch 2000.0 coordinates; V **magnitude**; **size** in arcminutes; **distance** in light-years, and the **constellation** that contains the cluster.

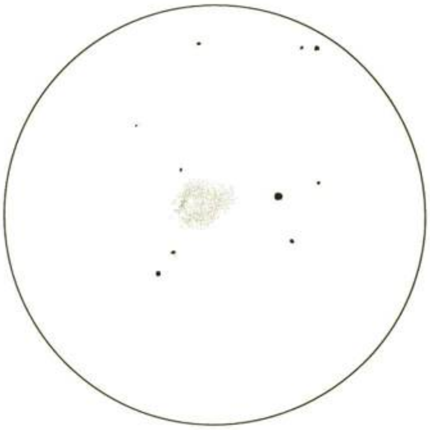
Sagittarius. The westernmost faint globular in this star group is **Terzan 5**, a brutally faint haze 50,000 light-years away with a 10th-magnitude star lying on its eastern edge. From this cluster, move a little more than 1½° southwest to find **Palomar 6**, a huge, highly obscured cluster in Ophiuchus. This group glows at magnitude 13.6, spans fully 7', and lies only 9,500 light-years away. It would undoubtedly be a much-observed cluster were it not blocked by the dark clouds of the galaxy.

Other challenges await in Sagittarius. Aim your scope smack dab in the middle of the Milky Way, about 1° north of the bright open cluster NGC 6520, to locate **Terzan 9**. At 16th magnitude, this is a tough challenge. Observers equipped with a 31-inch scope have spotted it: It's out of reach of my 25-incher. **Palomar 8** lies 2½° southeast of the open cluster M25. It is heavily obscured, lying almost directly behind the spine of the Galaxy. Low powers will not show the cluster: Try cranking up to 150x or more to reveal it. **Palomar 9**, just east of Nu (ν) Sagittarii, is the only Palomar cluster that looks like a globular cluster. At high power the cluster shows an almost stellar core surrounded by a large, faint haze.

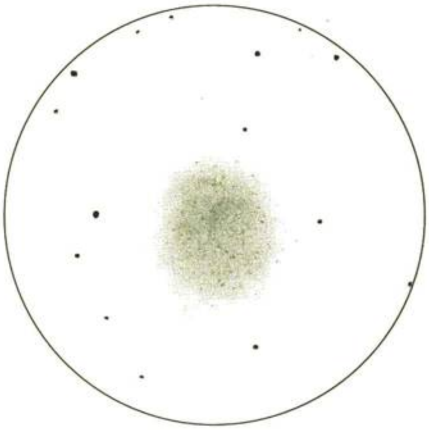
When you tire of Sagittarius, zip over to Sagitta and attempt to locate **Palomar 10**, 2½° southwest of the sprawling cluster Collinder 399, known as the Coathanger. Measuring 3.5' across and glowing at 13th magnitude, this object lies 30,000 light-years away. Moving around to Pegasus, where the summer sky dissolves into autumn, is the more challenging **Palomar 13**. This cluster lies less than 1° northeast of the barred spiral NGC 7479. This cluster is doubly tough: It's both small and faint.

The accompanying table lists 11 more faint globular clusters that will give you hours of fun. If you don't find these objects right away, even with a very large scope, don't give up. You're seeking photons that have traveled for tens of thousands of light-years through murky curtains of galactic dust. It's not an easy feat. Keep at it, though, and you'll succeed. ☐

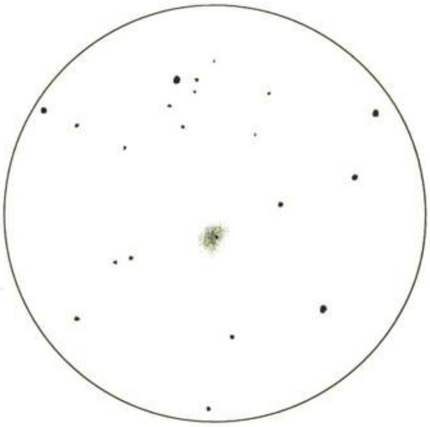
David Higgins is a U.S. Army staff officer in Oklahoma City who enjoys going after globulars and galaxies with his 25-inch "cannon."



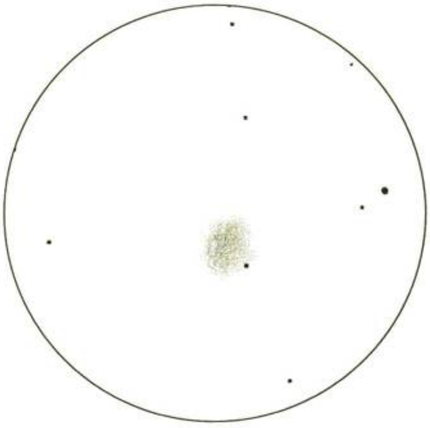
Palomar 4 in Ursa Major



Palomar 14 in Hercules

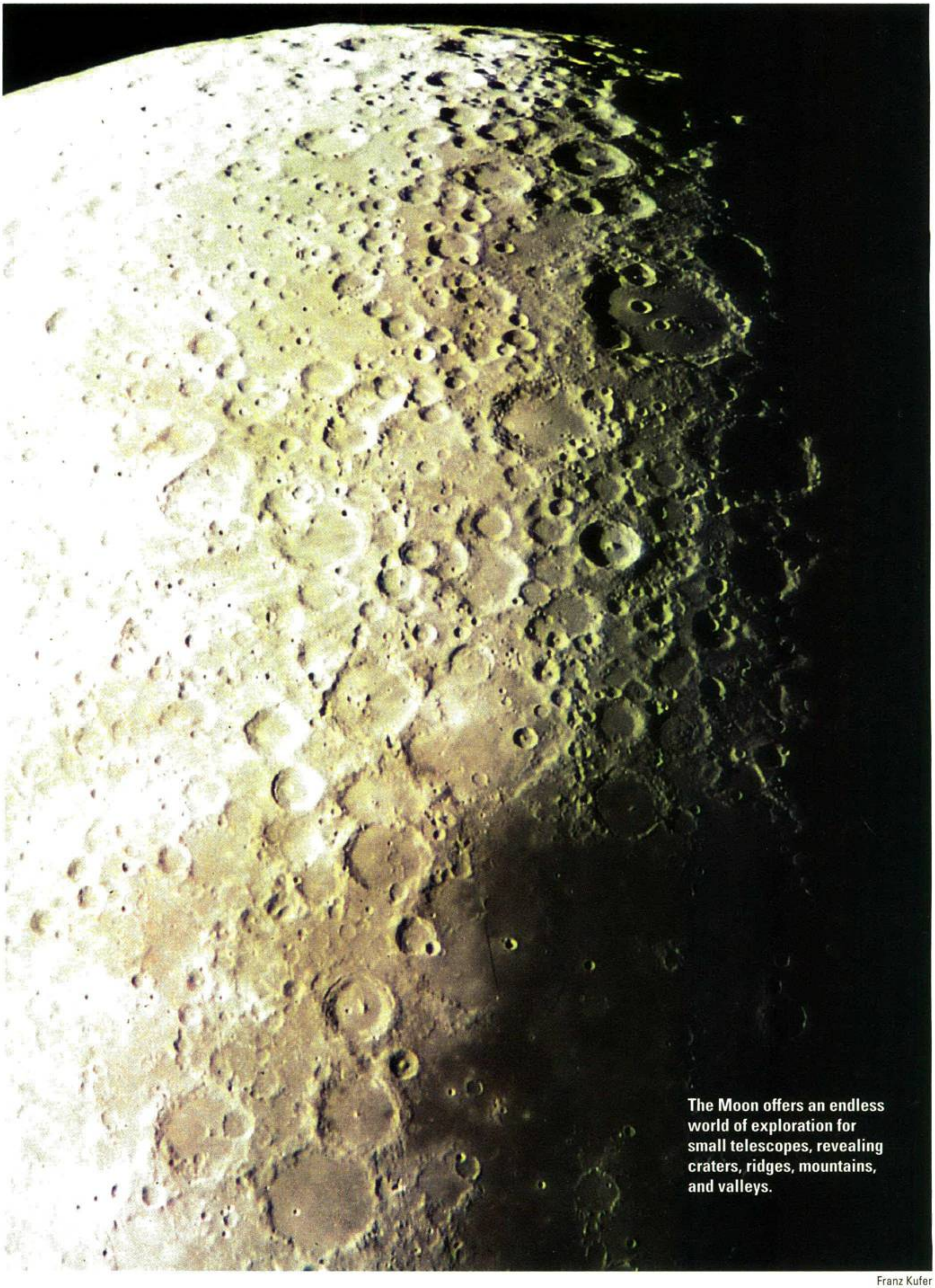


Terzan 2 in Scorpius



Terzan 12 in Scorpius

All sketches by David Higgins, made with a 25-inch f/5 reflector at 264x.



The Moon offers an endless world of exploration for small telescopes, revealing craters, ridges, mountains, and valleys.

Franz Kufer

Small Scope Showcase

Discover the Autumn Sky

The fabled 2- to 6-inch telescope packs a mighty punch, revealing far more in the sky than you might expect.

by Glenn F. Chaple, Jr.

Are you a member of that legion of ASTRONOMY readers who owns a small telescope but rarely uses it? Perhaps you've always believed that a mega-huge telescope is the only way to reach out and touch all those space places pictured on the pages of this magazine. Besides, you're overwhelmed by that confusing maze of stars and constellations that confronts you when venturing out at night. Your astronomy adventure just can't get off the ground.

Terrestrial observing lets you become familiar with your scope under daylight conditions.

Well, cheer up. You can capture comets, pursue planets, and even gobble galaxies with a common 60mm (2.4-inch) refractor or 3- to 6-inch reflector. And, by starting out slow, you won't get lost in space.

This month, we'll show the way to some of the finest small telescope sights of autumn. In future issues of ASTRONOMY, you'll explore the sky sights of other seasons. Stay with us and become a veteran space explorer who has visited more cosmic destinations than Captains Kirk and Picard combined. So get that little scope out of the closet and dust it off (or go out and purchase one, if you don't own a telescope). Your cosmic adventure is about to begin.

Veteran Skygazers Take Note

If you're a veteran skygazer who can't remember your last outing with a scope smaller than 6 inches, you don't know what you're missing. Small telescopes are extremely portable — a plus when you're traveling and can't fit your 20-inch Dob in the luggage — and they perform wonders with the trained eye. The well-equipped amateur astronomer knows that two telescopes, one large and one more modest in aperture, will cover almost any possible observing situation.

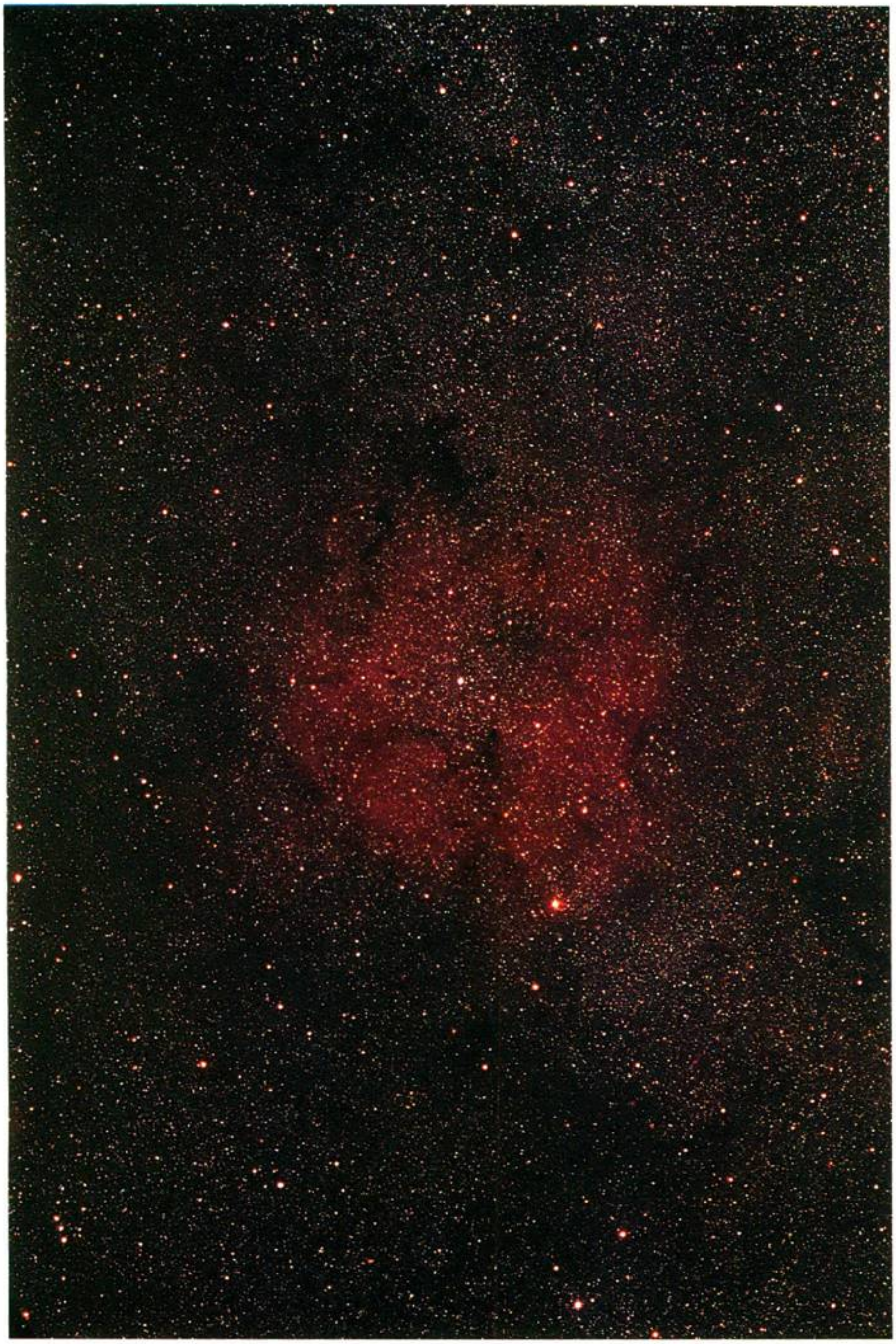
First Stop: Planet Earth

"Wait a minute," you protest. "I want to explore outer space with my telescope. Earth is, well — it's Earth." Have you forgotten that Earth is an outer space object — to be exact, third planet out from the Sun? A Martian astronomer would gladly give his left antenna for the views of Terra you get with a backyard telescope.

Terrestrial observing lets you become familiar with your scope under daylight conditions. You can practice aiming and focusing on stationary targets (sky objects continually move as Earth rotates). Try out the various eyepieces and accessories to see how they perform. Collimate a mirror or center a finderscope without fumbling around in the dark. It's a lot easier to

Joe Myers

A lunar eclipse like the one that takes place this month offers a dark, rusty Moon hanging eerily in the sky.


Gerald Rhemann

Herschel's Garnet Star, Mu Cephei, shines with an orange hue and sits below the big emission nebula IC 1396 in Cepheus.

read a telescope manual by sunlight than by flashlight. When you feel you could operate the telescope with eyes closed, you're ready to venture into the murky depths of outer space.

One Giant Step for Stargazers

The Moon is a delight. It's big, bright, and easy to find. Few naked-eye sights are more attractive than an autumn Full Moon, its silvery glow illuminating a frost-laden landscape. Many a skywatcher has eagerly pointed a telescope at this inviting target, peered into the eyepiece, and YOW! It's too bright. And it's tough to see any craters or mountains.

Lunar Lesson 1. The Full Moon is uncomfortably bright (though not the blinding disk that confronts large-scope viewers). Avoid eyestrain by using a Moon filter (an accessory that comes with most small scopes and merely screws into the eyepiece) or simply by limiting your gaze to a few seconds at a time.

Lunar Lesson 2. (You'll like this one.) Full Moon is a great time to view those dark lunar seas (maria) that create the "Man in the Moon." Also highlighted are the bright ray systems that emanate from relatively young craters like Aristillus, Copernicus, and Tycho. Tycho is arguably the most striking Full Moon feature. Bright streaks radiate outward for hundreds of kilometers, giving Tycho the appearance of some colossal spider clinging to the Moon's southern hemisphere. Before you grab your highest power eyepiece and start squinting, you should follow . . .

Lunar Lesson 3. Start out with low power (25x to 50x). You can view the entire Moon and identify the major maria and ray systems shown on the accompanying map. Once you've targeted an area of interest, study it with higher magnifications. This "low-power first" tactic is recommended for just about any sky object you wish to study.

Lunar Lesson 4. Full Moon is not the time to view craters and mountains. The Sun shining "straight down" on the Moon from our earthly vantage point erases the shadows that enhance the moon's rugged topography.

No matter when you view the Moon, magnification is critical. What is your telescope's magnifying power? That depends on the eyepiece you use. An eyepiece is inscribed with letters (abbreviations for its design), followed by a number (its focal length in millimeters). To find the magnifying power, simply divide the telescope's focal length (inscribed somewhere on the tube or on the focuser) by the eyepiece focal length. Example: a 700mm telescope with a 20mm eyepiece yields 35x. Couple that eyepiece with a 2x Barlow (an accessory lens that boosts magnification), and you have 70x.

The Full Moon of September 26/27 promises a real treat, an eclipse. A small telescope is your ticket to a

Don Bruns

Changing phases highlight Venus' telescopic appearance, and provide a display that observers can follow over weeks or months.

ringside seat for this special event (see page 68 for details). During the eclipse, view the Moon with high power and watch Earth's shadow slowly creep across the lunar surface. Invite friends, relatives, or neighbors over to see the show. Astronomy is the ideal hobby to share with others.

Saturn and Venus in the Autumn Sky

While watching the lunar eclipse, you may notice a bright "star" nearby. That's Saturn, which reaches opposition that same night and remains well-placed for viewing throughout the autumn months. Last year, Saturn was a disappointing sight for anyone trying to see its majestic ring system. The rings were edge-on to our line of sight and remained invisible. This year they appear slightly tilted and can be glimpsed with powers as low as 50x. Look for Titan, a huge moon bigger than Mercury, but appearing like a tiny star next to Saturn. Titan orbits Saturn once every — wait a minute. Why not make nightly observations of Saturn and Titan and determine this moon's orbital period for yourself? (Hint: it's less than a month, so this isn't a long-term project.)

Last spring, you may have seen Venus shining high and bright in the western sky after sunset. Venus left the evening sky this summer, but it's back as a morning planet. Go outside about an hour before sunrise, face east, and — bingo. You can't miss what is the brightest object in the sky after the Sun and Moon. Like the Moon, Venus undergoes phase changes, which you can follow with medium to high magnifications (50x to 100x and up). Keep tabs on this lunar charade with weekly observations from now until Venus drops into the glare of the rising Sun at year's end. Don't expect to see a wealth of spectacular lunarlike terrain. Venus is perpetually covered by a dense, cloudy atmosphere and presents an essentially barren white disk.

Comet Hale-Bopp

For many months, you've been hearing about the pending arrival of Comet Hale-Bopp, even as you marveled at Comet Hyakutake. Wait no longer. Hale-Bopp is here, and it's an easy mark for small scopes. Your first task is to locate the comet on a clear, moonless night, preferably from an observing site removed from bright artificial lights. See "Showtime for Hale-Bopp," July 1996, for a finder chart showing the way to Hale-Bopp. The comet should be a naked-eye object during autumn, sporting a ghostly tail. When viewing the comet with your telescope, use the "low power first" rule. In time Hale-Bopp will grow so large that medium and high powers won't show it entirely.

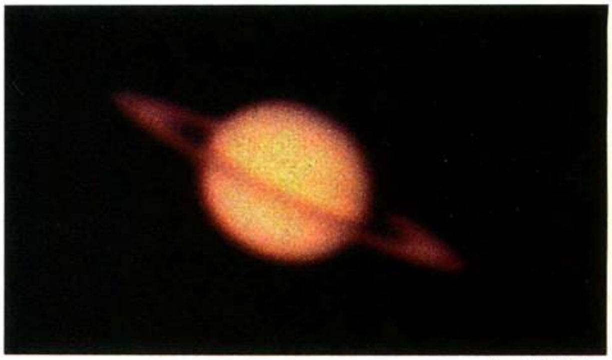
A Quantum Leap

A telescopic journey to the stars holds the promise of any celestial adventure, but be forewarned: The typical star is hardly the visual treat the Moon and planets are. No matter what magnification, all you'll see is a tiny point of light (if you see a large disk, something is wrong with your focus). Stars are shrunk by distances typically a million times greater than the gap separating us from Venus or Saturn.

Stars may not look bigger through the telescope, but they are brighter and more colorful. Try the bright star Deneb (Alpha [α] Cygni) in Cygnus. One of the three 1st-magnitude stars that form the Summer Triangle, Deneb is visible throughout the autumn as well. Impressive to the unaided eye, Deneb sparkles diamondlike in a telescopic field. As you gaze at this cosmic gem, you're looking at light that left its surface 16 centuries ago.

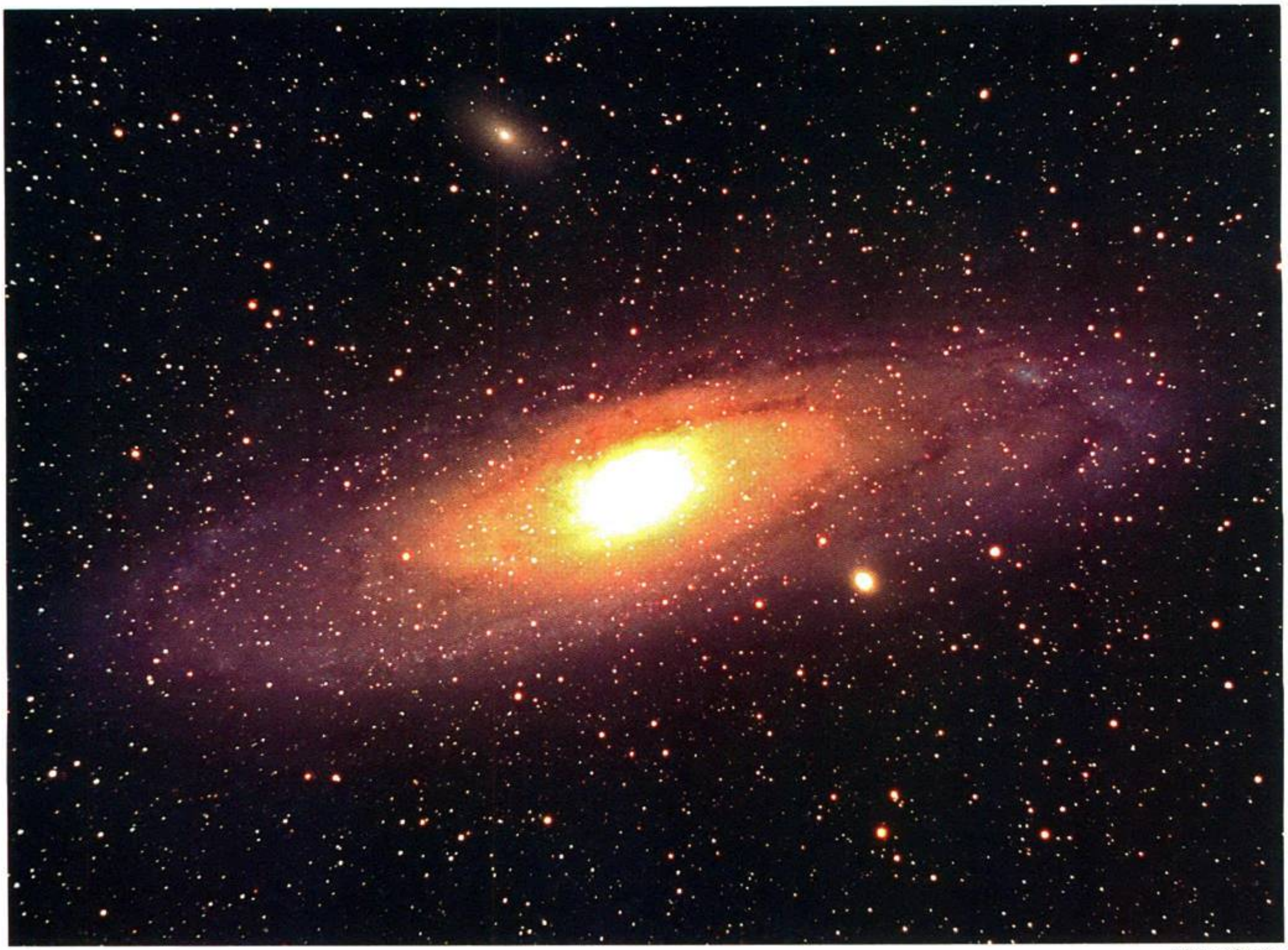
Hale-Bopp should be a naked-eye object during autumn, sporting a ghostly tail.

After admiring Deneb for a few minutes, try your luck with the star Mu (μ) Cephei. Mu Cep is much fainter than Deneb, its magnitude varying between 3.5 and 4.5. It is famous for its color, a vivid red hue that inspired the 18th-century astronomer William Herschel to nickname it the "Garnet Star." Whether you



Donald C. Parker

The ringed planet Saturn offers a spectacular view. Almost any telescope reveals the system of rings.

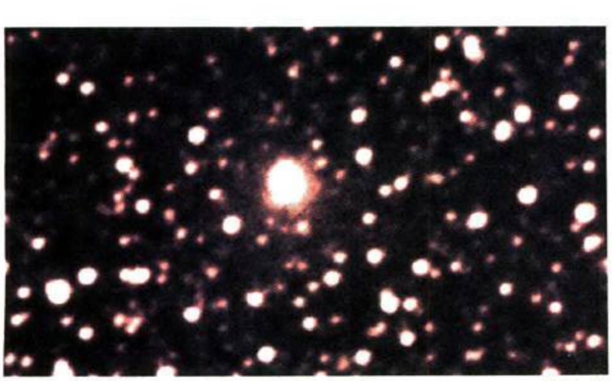


Michael Stecker

The Andromeda Galaxy is the most distant object visible to the unaided eye. Small scopes reveal its bright bulge, traces of faint spiral arms, and two small galaxies orbiting it.

see it as a gem-like garnet or ruby, or as a drop of cosmic blood, Mu Cephei is a startling sight. It's farther away than Deneb, being some 2,800 light-years away.

Have you ever seen double, astronomically speaking? While a single star may not be a particularly inspiring telescopic sight, the addition of a second star close by creates a vision of delicate beauty. To double your autumn observing pleasure, we introduce the Gamma Gang — Gamma (γ) Delphini, Gamma Arietis, and Gamma Andromedae. All are bright and easily separated double stars, each with something unique to offer. Start with Gamma Del, a magnitude 4.5 and 5.5 pair separated by 10 arcseconds. This means it should be easily breached with a magnification of 45x to 60x. Most newcomers see both stars as white, but veteran observers detect subtle shades of yellow and blue. If skies are steady, scan the surrounding area for Σ2725 (mags 7.5 and 8, sep. 6"). This faint pair requires a magnification of 90x or more. The next stop is the striking twin system Gamma Ari. The member stars are both white, shine at magnitude 4.8, and are separated by 8". Gaze at this duo and you'll feel as though you're looking at the headlights of some distant cosmic automobile. Our final double, Gamma And, is the most colorful. This beautiful gold and blue combination is comprised of magnitude 2.3 and 4.8 stars separated by 10". Which Gamma Gang member do you find most appealing?



Pedro Ré

Comet Hale-Bopp is now brightening toward its spectacular show of next spring. Small scopes will show weekly changes.

Astronomy is a great hobby that evolves throughout your lifetime. As you gain experience with your telescope, you may find yourself falling into the ranks of the so-called serious amateur astronomers. Serious work is okay, but don't forget astronomy's fun side. For autumn skygazing that's pure fun, check out Epsilon (ε) Pegasi, the Wiggle Star. Viewed with a magnification of 50x to 75x, Epsilon proves to be a wide, unequal double star, hardly the visual treat to match any of the Gamma Gang. But wait. Something magical happens when you gaze at this pair while jiggling the telescope tube back and forth (be sure it's in a direction perpendicular to a line joining the two stars). The companion seems to sway to and fro like a clock pendulum. What's happening? Its light takes longer to register on your eye's retina. Each time the field reverses direction, the faint star seems to continue briefly in its original direction. The Wiggle Star provides an amazing illusion, and a pleasant change-of-pace from serious skygazing.

On into Deep Space

Think a double star is a visual treat? Try a double cluster. On a clear, moonless night, look for a fuzzy patch of light between the constellations Cassiopeia and Perseus. A low-power telescopic view transforms this patch into a pair of open star clusters — two swarms of cosmic fireflies shining side-by-side. This is the Double Cluster (NGC 869 and NGC 884), one of the finest sights in the sky. Although a small scope reveals a few dozen of the clusters' brightest stars, the view is spectacular. These clusters float in the Galaxy some 7,200 and 7,500 light-years away.

You may find yourself falling into the ranks of the so-called serious amateur astronomers.

Open clusters may be star-rich, but their stellar populations pale when compared with globular star clusters. A typical globular cluster can be home to as many as one million stars. Most globulars inhabit the summer evening sky in a region concentrated around our Galaxy's center. An exception is M15, located near our wiggly friend Epsilon Peg. In small telescopes, this cluster appears as a fuzzy glow less than half the Full Moon's apparent diameter. Even under high power, M15 remains unresolved. Alas, only a large scope resolves its stellar legions. Still, it's a treat to admire this remote object, which lies some 30,000 light-years away.

Tom Koed

The Double Cluster in Perseus offers two for the price of one. Low-power fields reveal twin fields of sparkling stars.

Bob Sandy

The brightest star in Cygnus, Deneb (at right, seen with the North America Nebula), has a brilliant blue-white hue that dominates the early autumn sky.

Thirty thousand light-years may seem like a vast distance, but it's a walk around the block when compared to the 2.2 million light-years that separate us from the Andromeda Galaxy (M31). If you're a beginner, you might assume that something as remote as a galaxy would be tiny and faint, visible only under the highest possible magnification. Wrong. The Andromeda Galaxy can be glimpsed with unaided eye; in the telescope, it spans an area larger than the Full Moon. Use low power and look for a large, oval patch of light. This is the bright nucleus of the galaxy, elliptical because M31 is tilted slightly edge-on to our line of sight. The nucleus is usually all the first-time viewer ever sees, but trained eyes see M31's faint spiral arms and its smaller satellite galaxies, M32 and NGC 205. It's a humbling experience to gaze at the misty glow of hundreds of billions of distant stars and wonder if anyone there is looking back at us.

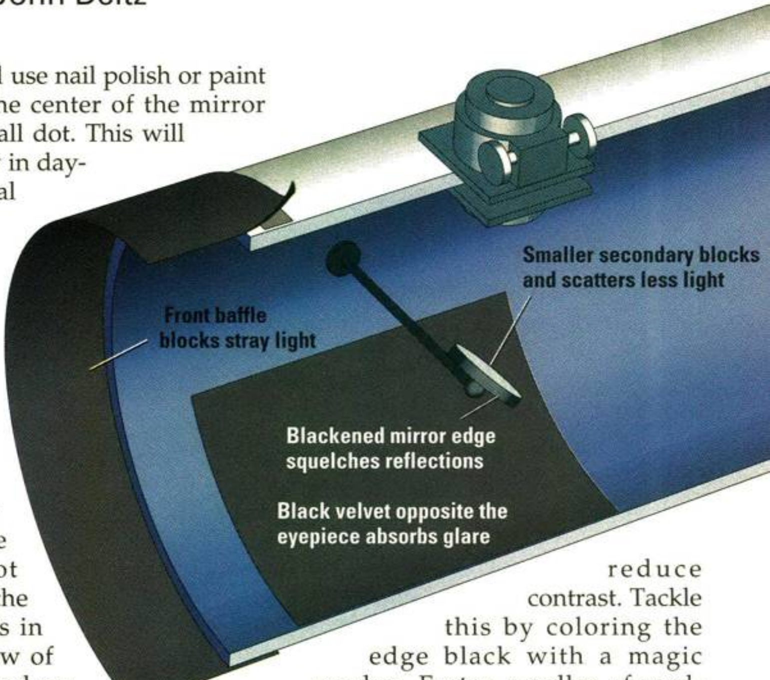
There you have it — a cosmic journey that took us from our home planet, right beneath our feet, to a galaxy 20 million trillion kilometers away. The little telescope that tucks away so nicely in your closet is in reality a starship with capabilities that would rival the *Enterprise* itself. ☐

Glenn F. Chaple, Jr., is a teacher living in Townsend, Massachusetts. He has written for Astronomy *and* Deep Sky *magazines frequently, and he is the coauthor of the* Edmund Mag. 6 Star Atlas.

Make Your Scope Light-Tight

Wage war against the light pollution bouncing around inside your Newtonian or Dobsonian telescope.

by John Deitz


Smaller secondary blocks and scatters less light
Front baffle blocks stray light
Blackened mirror edge squelches reflections
Black velvet opposite the eyepiece absorbs glare

Every run-of-the-mill Newtonian telescope is simply a tube with openings on both ends. Although the front end allows "good" observing light in, neither end discriminates good from bad light. Most of the time the consequences of scattered light are subtle, perhaps a slight loss of image contrast muddies an otherwise stunning view of the planets. At other times, unwanted light may hide a nebula's soft glow.

Despite these persistent problems, Newtonian owners seldom apply some easy fixes that would cut contrast problems in half. These remedies don't require a degree in rocket science, just a few materials and some simple tools. The only other commodity invested is time, which is more than made up for by the higher contrast images a scope provides for years to come.

Universe in Black

This first set of stray-light-busters merely requires paper, brush, a black marker, and flat black paint.

Center-dot the primary mirror to aid in alignment. Many poor-contrast problems stem from optics that are out of alignment. Optical alignment, or collimation, requires you to know the exact center of your primary mirror. Dead reckoning isn't enough to do this; you'll need to construct a center template.

Punch a ⅛-inch hole into the center of a round piece of paper that's the same size as the primary. Now center the paper over the mirror and use nail polish or paint to mark the center of the mirror with a small dot. This will aid greatly in daytime optical alignment (see "Test Your Scope's Optics," July 1994). Don't worry about the black dot affecting the image. It's in the shadow of the secondary mirror and not a part of the optical path.

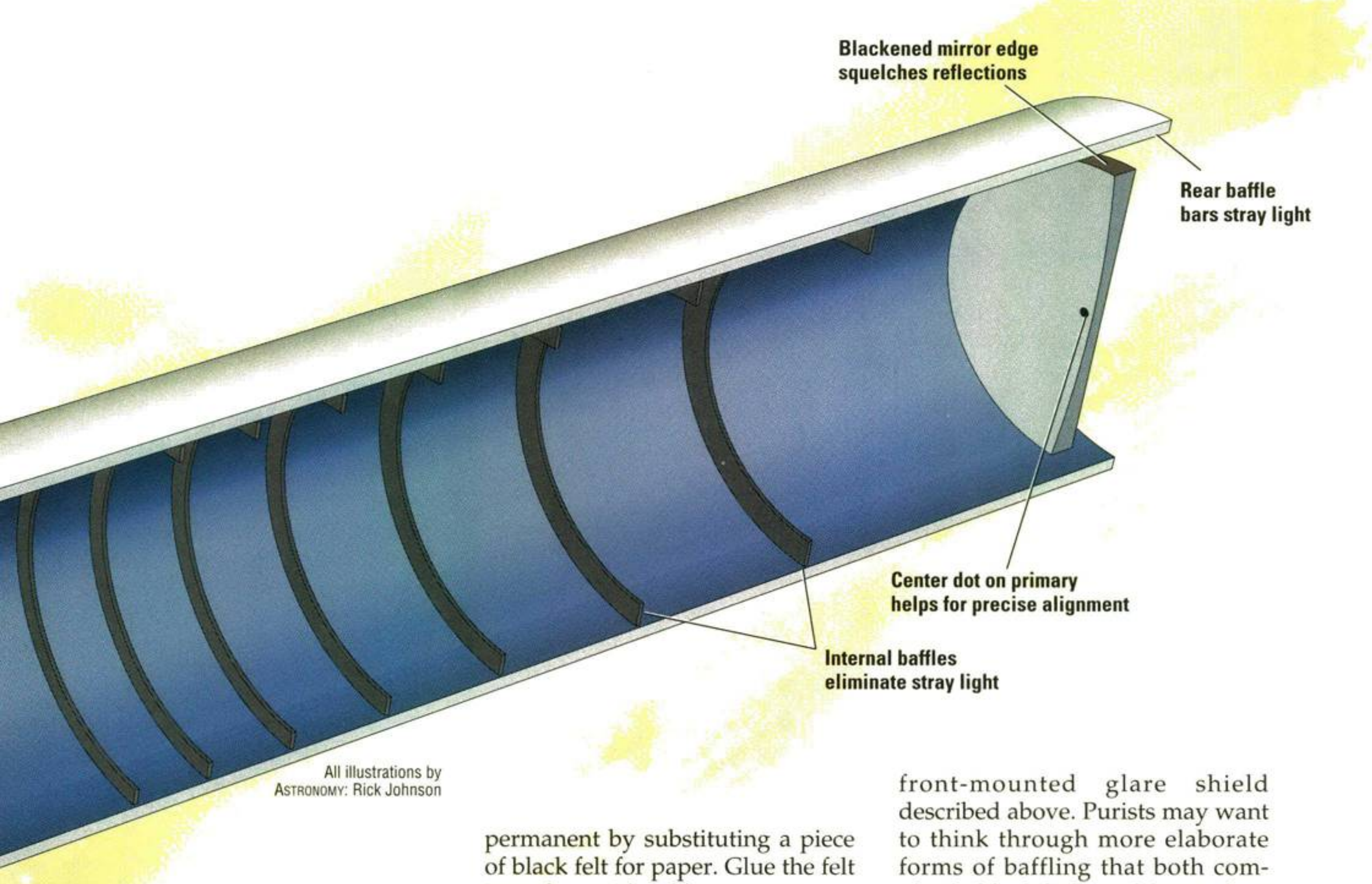
Paint the backside of the diagonal. Sometimes the back of a diagonal mirror is visible through its mount. Although its contribution to scattered light may be small, nonetheless it is real and very easy to fix. Just paint the backside black, along with any packing that might be visible behind the mirror. While you're at it, verify that the entire secondary mirror mount is black. Pay particular attention to mounting hardware like bolts and screws.

Black out the primary mirror's edge. Remove the primary mirror from its cell and closely examine the front edge. It's likely been beveled to avoid a sharp edge. Any reflective coating on this beveled edge will scatter light and reduce contrast. Tackle this by coloring the edge black with a magic marker. Fasten a collar of cardboard around the mirror to serve as a guide and then simply draw around the edge.

Avoid protruding mirror clips. You'd be reluctant to buy a refractor with clips over its front element, so why settle for front clips that secure a primary mirror to its cell? However negligible, these clips scatter light and add to diffraction. Some mirror cells on the market keep the use of front clips to a minimum. Scan the ads in this magazine for manufacturers who offer them. Some lightweight mirrors, those smaller the six inches, might even stay put with Velcro. If you do use clips, however, make sure each one is painted black to reduce reflections.

Dab and Shield

Sometimes stray light demands


Blackened mirror edge squelches reflections
Rear baffle bars stray light
Center dot on primary helps for precise alignment
Internal baffles eliminate stray light

All illustrations by ASTRONOMY: Rick Johnson

you look beyond the simple application of black paint. More elaborate fixes require more time, but yield even more striking results.

Darken the eyepiece's line of sight. The tube wall opposite the focuser will often scatter light into an eyepiece's field of view and reduce image contrast. This glare is most noticeable when something bright like the Moon lies a few degrees away from an object centered in the telescope

To get an idea of how bad this type of stray light is, try an experiment at next full Moon. Carefully cover the diagonal mirror with black fabric, aim the scope at the Moon, and then glance through the eyepiece. You'll be greeted with a muddy, gray glow. This is light scattered from the tube wall opposite the focuser.

Now cut a circle out of black construction paper with the same diameter as your primary mirror and center it against the tube wall opposite the focuser. You should notice that the eyepiece view looks darker than before. Make this fix permanent by substituting a piece of black felt for paper. Glue the felt into place with rubber cement.

Install a front glare shield. Shield your telescope from outside glare by installing a glare shield on the scope's front opening. Such a shield works best to block light adjacent to your observing site, like light from nearby streetlights. Ideally, it should extend beyond the tube's opening by one primary mirror diameter.

Test drive the glare shield by first using black construction paper, then build a more durable extension that stays in place with Velcro. Construct the final shield from a flexible plastic material called "Kydex," available at most home improvement supply stores. This type of shield peels off the scope and lays flat for storage.

Install a rear glare shield. Unwanted light may find its way into a Newtonian through the tube's bottom opening. Whether this light comes from streetlights or moonlight that bounces off the ground, the contrast-reducing effects are the same. Defeat this problem by making a rear-mounted light shield much like the front-mounted glare shield described above. Purists may want to think through more elaborate forms of baffling that both completely block light and let air flow cool down the scope.

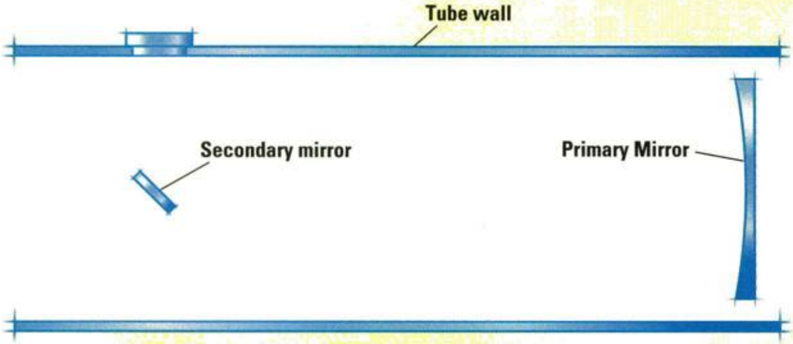
Baffle the Enemy

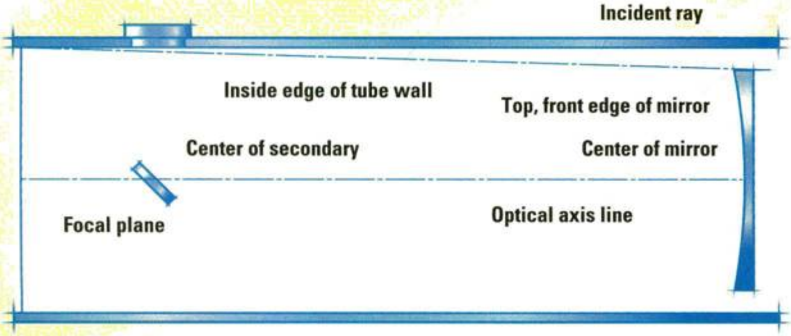
This next procedure is by far the most ambitious and demanding, but it also offers the biggest payoff. Installing interior tube baffles eliminates most, if not all, of the reflections internal to your telescope's optical system.

To get a feel for the problem these baffles seek to cure, try another test under moonlight. Point the scope at the Moon after removing the primary mirror and cell. Aim it so the Moon is blocked by the secondary mirror. See all that light on the tube wall? Much of it scatters onto optical surfaces, lowering image contrast. Internal baffles minimize this problem by reflecting and/or absorbing stray light before it can strike the primary or secondary mirror.

First, make yourself a 1:1 scale drawing of your telescope on a giant sheet of white paper. Besides the tube, draw in the secondary mirror's position, size, and tilt, as well as the location of the primary

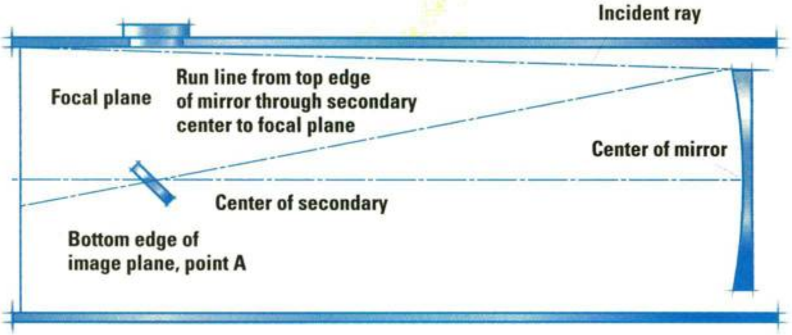
Installing Baffles One Step at a Time


Tube wall
Secondary mirror
Primary Mirror


Incident ray
Inside edge of tube wall
Top, front edge of mirror
Center of secondary
Center of mirror
Focal plane
Optical axis line

1

- Draw in incident ray
- Draw in optical axis line
- Draw in focal plane


Incident ray
Focal plane
Run line from top edge of mirror through secondary center to focal plane
Center of mirror
Center of secondary
Bottom edge of image plane, point A

2

- Determine point A, the bottom edge of the image plane

mirror. From here on out, you'll only be using the top half of your tube drawing.

Now use a straight-edge to draw one ray of incoming light, an incident ray, which skims the top inside edge of the tube's front opening to strike the front top edge of the primary mirror. The gap between this line and the tube wall defines the height of each baffle to come.

Next, define the mirror's focal plane. Draw a line perpendicularly from the middle of the primary mirror through the center of the secondary mirror, with a length equivalent to the mirror's focal length. This line represents the optical axis. (Calculate focal length by multiplying the mirror's diameter by its f/number.) Cap this line with another that's perpendicular to both tube walls. This line defines the focal plane.

Only the center section of the focal plane, the image plane, sees light. Plot one side of this plane by extending a line from the top edge of the primary mirror through the secondary's center to the focal plane. Label the point where this line and the focal plane meet with a letter A. This point marks one edge of the image plane.

Now you're ready to figure the first baffle's position. Draw a line that connects point A to the top, rearmost, inside edge of the telescope tube. The first baffle's position is where this line crosses the incident ray drawn earlier. The baffle's height is a perpendicular line dropped to the tube wall from this intersection point.

Figure the second baffle's position by connecting a line between point A and the bottom of the first baffle. For the third baffle, a line connects A to the bottom of baffle two, and so on. Repeat this process for subsequent baffles until they become too tightly spaced or too small to measure on the drawing. The finished drawing shows two things: Baffle height and spacing.

Now it's time to make the baffles. First measure the height of each baffle line on your scale drawing. Use a compass to scribe two concentric circles on heavy, flat black poster board, an inner and outer circle separated by each baffle's height. Cut out each baffle with an Exacto knife.

Finally, return to the tube, which has its secondary mirror assembly and primary mirror cell removed. Space each baffle inside the tube per your scale drawing, and then glue into place. Work from the back of the tube forward.

An easier alternative might be to mount the baffles on three thin runners into which grooves are cut for each baffle. This whole assembly then slides into the telescope tube as one piece. After the baffles are in, apply one more layer of flat black paint to the interior before reinstalling the optics.

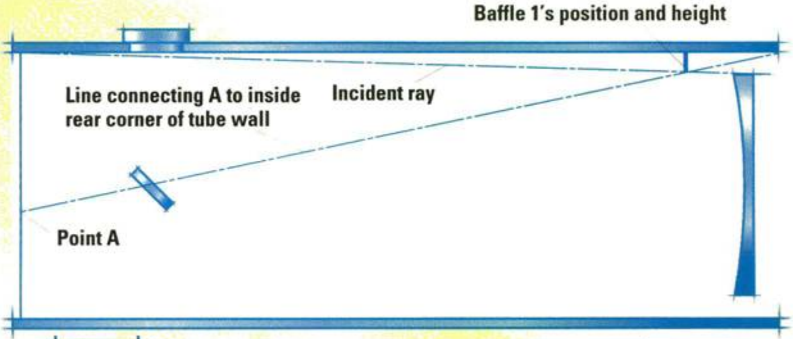
Hardware in Motion

One last solution doesn't require the color black at all. Common sense says the best way to cut down on scattered light is to not scatter it in the first place. And what scatters light the most inside a telescope tube? The secondary mirror and its support, which lies in the path of incoming light.

A smaller secondary that scatters (and blocks) less light offers improved contrast. But to accommodate a smaller secondary, the primary mirror must move back deeper into the tube to cast a smaller cone of light. And if the mirror moves, so does its focal point. You'll need a so-called "low-profile focuser" that lets eyepieces come to closer focus. Manufacturers that sell smaller secondaries and low-profile focusers will offer advice on what combination and placement best suits your optical system.

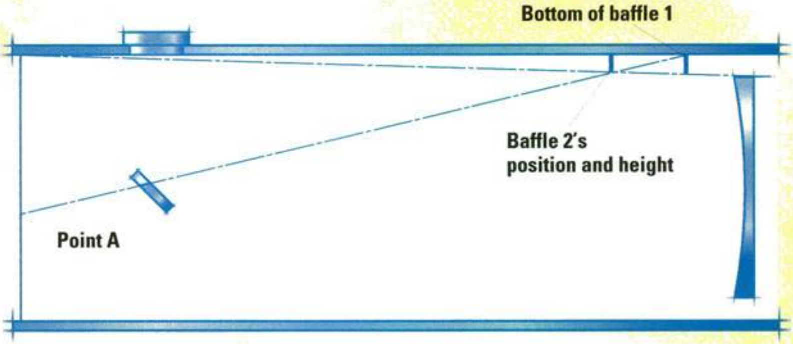
Taken separately, each of these stray light solutions might only marginally improve the contrast you see in any given image. But as your eye becomes more discerning, even the subtlest of improvements makes a world of difference. Eventually as you make several improvements, you'll gain an upper hand on that other form of light pollution, one that rebounds around the inside of your telescope every night. □

John Deitz uses his souped-up Newtonian to observe deep-sky objects from suburban Chicago.


Baffle 1's position and height
Line connecting A to inside rear corner of tube wall
Incident ray
Point A

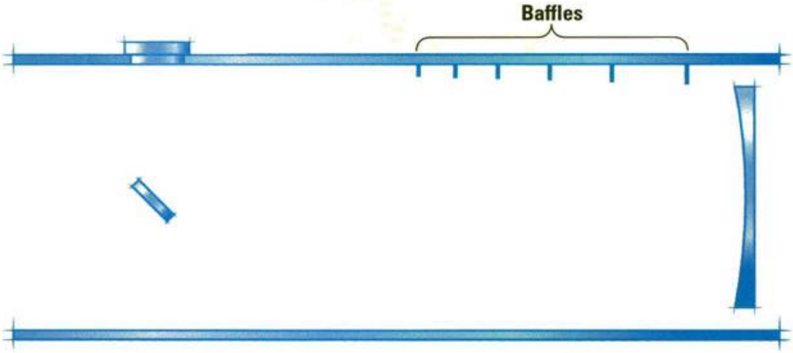
3

- Draw a line between pt. A and the top, innermost edge of tube wall
- Where this line and incident ray touch is baffle 1's position and height



4

- Draw a line similar to step 3, except connect it to the bottom of baffle #1. This gives position and height of Baffle #2
- Repeat this step for subsequent baffles, moving up the tube wall until baffles get too small to measure



5

- Use scale drawing to figure inside and outside diameters of real baffles
- Note baffle spacing along tube wall
- Cut baffles out of black poster board and glue into your telescope

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The **Star Hopper**™ *Dobsonians are designed for beginners yet they include many advanced features that even experienced observers will appreciate that are not available on any competitive models.*

- **6" f/8 and 8" f/6 models.**
- The **Dovetail Balance System** featured on the **Star Hopper**™ provides a smooth low friction altitude bearing that can be quickly and easily balanced when using optional accessories such as finderscopes or heavier oculars. Without proper balance, fine aiming adjustments are difficult, such as centering an object in a high power eyepiece. **Celestron** is the only company to offer an adjustable counter balance system standard on its Dobsonian telescopes.
- The **Star Hopper**™ **6"** and **8"** primary mirrors are housed in 8" and 10" ID tubes respectfully. The oversized flat black anti-reflective painted tubes reduce light scatter and tube currents. These features increase image contrast and improve "seeing" when viewing planets and the Moon.
- The **V-Spectrum LTM Optical System** features a unique molded **Pyrex** mirror, **multi-coated** for increased reflectivity, that provides superior optical and thermal qualities and it is mounted on the **Pinnacle** mirror cell.
- The **V-Spectrum LTM (Low Thermal Mass)** mirror is manufactured and figured to reach the optimal marriage of weight to optical surface resulting in a mirror with 40% less mass than traditional mirrors. Reducing the mass lowers the "cool down" period required to bring the mirror to ambient temperature and leaves more time for observing. An optional fan can be placed behind the **Pinnacle** mirror cell to create a laminar flow of air over the **V-Spectrum LTM** primary mirror to optimize the mirror for planetary and high power observations..
- Our unique and heavy duty, single vane secondary mirror bracket creates minimal obstruction allowing more light to reach the primary.
- Our unique mount features a 10° angled rocker box which increases stability.
- Ultra smooth motion in both axes for easy finding and observing of objects.
- Included standard are a smooth operating 1¼" Rack and Pinion Focuser, a handy Collimation Tool, 25mm SMA (52°) Eyepiece – 1¼" (49x).
- Numerous accessories are available including various pointing aids — from a traditional 6x30 Finderscope, to a state-of-the-art zero power red dot pointing device — the **Star Pointer**, to the Astro Master® models to computerize your telescope.
- Manufactured at Celestron's factory in the U.S.A.
- All of the above features and yet an economical price.

CELESTRON
STAR HOPPER
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STAR HOPPER

CELESTRON EQUATORIAL NEWTONIAN TELESCOPES

C4.5 Its 900mm focal length (f/7.9) optical system is housed in an aluminum tube. The mirrors (primary and secondary) have multi-coatings for improved contrast and resolution. The premium optics are manufactured in Japan to rigid **Celestron** specifications.

The **C4.5** uses the Polaris mount which is a very rigid German equatorial type. The very rigid wood tripod is fixed in height for added stability and is supplied with an accessory tray. A quote from *Astronomy Magazine*, "the **C4.5** stands out from the pack by having by far the best mount. Its Polaris mount is wonderful. Solid. Smooth. And with a damping time of two seconds. It was a joy using this telescope." "This is a first-rate telescope that outclasses the competition in the popular 4½" class of Newtonians." Further they said, "the C4.5 star images were classic textbook Airy disks".

Standard accessories include a 26mm multi-coated Plössl Eyepiece – 1¼" (35x), high quality 6x30 Finderscope and a 1¼" Focuser.

Firstscope 114 Its 910mm focal length (f/8) optical system is housed in an aluminum tube. This high quality yet economical telescope is made in a modern, high quality telescope factory in China to **Celestron's** specifications.

The equatorial mount is stable and includes setting circles in both axes as well as slow-motion cables in both axes for easy tracking. The wood tripod is adjustable in height and includes an accessory tray.

Standard accessories include a 5x24 Finderscope, 1¼" Focuser (with a .96" adapter), 20mm H–.96" Eyepiece (46x), 4mm SR–.96" Eyepiece (228x), 2x Barlow Lens –.96"

A **Firstscope 114 Deluxe** model is available which replaces all .96" accessories with two high quality 1¼" eyepieces – 25mm SMA (36x) and 10mm SMA (91x). The 1¼" accessories give you sharper views, a wider field of view and better eye relief.

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For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

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NEW PRODUCTS

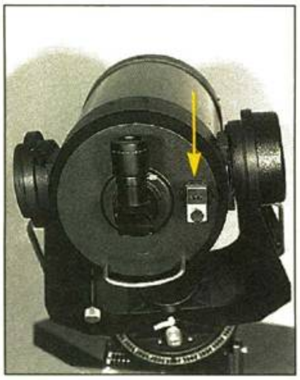
Night Vision Equipment

NIGHT RANGER
BAUSCH & LOMB

Bausch & Lomb Sports Optics now sells two night-vision viewers. The Night Ranger 150 Monocular (top) weighs 16 ounces and is powered by two AAA batteries. The Night Ranger 250, which allows for viewing with two eyes, weighs 26 ounces and operates on a standard six-volt lithium camera battery. Both have f/1.4 optics that yield a 40° field of view. The viewers are water resistant and feature an automatic brightness shutoff to protect key light-sensitive components from damage. Each also has an indicator that tells when battery power gets low. Night Rangers come with a carrying case with shoulder strap and a one-year warranty.

Bausch & Lomb Sports Optics, 9200 Cody, Overland Park, KS 66214; (800) 423-3537 or (913) 752-3433; fax, (913) 752-3489. The Night Ranger 150 Monocular: $1,925 (list); Night Ranger 250: $3,855 (list).

Digital Focus Counter



JMI's digital focus counter (arrowed) attaches to any Schmidt-Cassegrain telescope's focusing shaft to provide an extremely accurate readout of the focuser's position. This is useful to CCD users, who need to calibrate a precise point of focus before taking a picture. The unit's white-on-black, three-digit display measures a focusing knob's position to 1/500 of a complete rotation. Models fit all SCTs five inches in aperture or larger.

Jim's Mobile Inc., 810 Quail St. Unit E, Lakewood, CO 80215, (800) 247-0304; fax, (303) 233-5359. The DFC digital focus counter: $79 plus shipping. Specify SCT make.

Dobsonian Equatorial Platform

Build a Poncet equatorial platform for your Dobsonian with this kit from TL Systems. The platform handles telescopes up to 13 inches in size and tracks for about one hour before the drive needs "winding." The mount works in the Northern or Southern Hemisphere, within latitudes 20° and 60°. Plans come with mechanical parts; you supply the plywood and Formica. An optional printed circuit board controls a motor drive for slewing.

TL Systems, 2184 Primrose Ave., Vista, CA 92083; (619) 599-4219; e-mail, tlsystems@ix.netcom.com; URL, http://www.sunspots.com/tlsystems/. Equatorial platform kit: $109; Optional motor drive slew circuit board: $40.

New Line of CCD Cameras

First Magnitude's SpecIM line of CCD cameras features extremely low dark current previously unattainable by comparable, thermoelectrically cooled cameras. Chip sizes in the cameras range from 512x512 to 1552x1032 pixel arrays. Camera heads have a diameter of 10 cm, a length of 9 cm, and weigh 1.2 kg. The camera digitizes and outputs pixels at 165,000 pixels/second, 16 bits/pixel, into a PC's parallel printer port. Your choice of DOS or Windows acquisition software monitors CCD performance by looking at readout noise, dark current, and linearity. The software also controls camera temperature to within 0.1 ° C, and saves acquired images in FITS or GIF formats.

First Magnitude Corporation, 519 South Fifth St., Laramie, WY 82070; (307) 745-3743; fax, (307) 766-4026; e-mail, firstmag@delphi.com; URL, http://www/wyoming.com/~Johnson/fmc.htm. The SpecIM line of CCD cameras start at $2,450.

NA C-MOUNT ADAPTER

New Products presents announcements issued by manufacturers. ASTRONOMY *assumes no responsibility for the product information supplied. Prices are suggested retail. Suppliers should send announcements and color photographs to the attention of John Shibley, P.O. Box 1612, Waukesha, WI 53187, or newprod@astronomy.com.*

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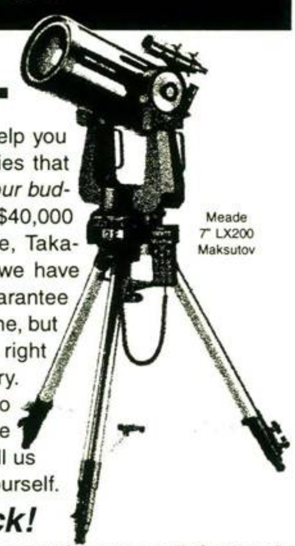

Meade
7" LX200
Maksutov

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Hardly a day goes by that we don't get a note like the one reprinted below, or a call that goes something like this: "Your ads are right. So and so on the East Coast advertises low prices – but they don't have what I want in stock, they couldn't answer *any* of my questions, and they wanted my credit card number before they'd even *talk* to me. They said if I wanted to ask questions, I should call the manufacturer . . . and then they hung up on me!" One of our customers added, "If I wanted that kind of abuse, I would have called my ex-wife."

You need more than a camera store clerk with a price list and a wild guess to help you pick the right scope. You need someone who will take the time to listen to what *you* need, someone with the experience to help you get the most scope for your dollar. At ***astronomics***, we've been helping people choose the right scope since 1979. We *have* the experience to help you pick the scope and accessories that best fit your needs . . . *and your budget*. With scopes from $329 to $40,000 – Meade, Celestron, TeleVue, Takahashi, Questar, and more – we have *all* the right stuff. We can't guarantee we have the perfect scope for everyone, but we'll do our best to help *you* pick the right scope from the more than 75 we carry.

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Meade prices are usually the same anywhere you call. So there's no sense in buying from a dealer who charges your credit card (and sometimes puts more on your card than you expected), then makes you wait and wait until he gets around to ordering what you want. Not when you can get what you want *right now* . . . from ***astronomics.***

The new TeleVue Ranger ED refractor and all the TeleVues – *in stock!*

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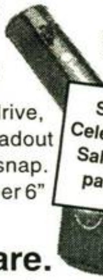
If it's something from TeleVue that can help you see more in the heavens and see it better, we probably have it in stock. Call us and see for yourself.



Celestron 8"
Star Hopper
Dobsonian

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And we have the new Celestron Star Hopper 6" and 8" advanced Dobsonians in stock, too!

See our Celestron 1¢ Sale ad on page 27.

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Our free catalog tells how to pick the right Celestron, Meade, Questar, Takahashi, or TeleVue.

Call us at (405) 364-0858 (or E-Mail us at Compuserve or AOL) for your *free* copy of our catalog 96AST covering the scopes and accessories we stock – from Celestron, DayStar, Edmund, JMI, Kendrick, L-5 Systems, Lumicon, Meade, Questar, SBIG, Takahashi, TeleVue, and more. We'll include our 8-page guide on how to pick the right telescope and your discount prices on the hundreds of products we carry (sorry, U. S. sales only). The catalog is yours for only the cost of a one minute phone call. The information we send will make it the most useful one minute you'll ever invest in astronomy.

> P.S. After months of pouring over telescope literature, I was ready to take THE BIG PLUNGE. I had been impressed with the Astronomics ads as they appeared to be "the most sincere in all the land". Yet I was tempted to and did indeed call companies with seductive ads proclaiming inexpensive merchandise. YOU WERE RIGHT! Other companies tried to sell me the telescope they wanted me to buy, not the one I wanted to buy. Others "kinda" knew the specs of what they were selling. I called Astronomics twice, and both times I received clear, honest information. The woman with whom I spoke had the firsthand knowledge. and natural pleasantness that one seldom encounters today.
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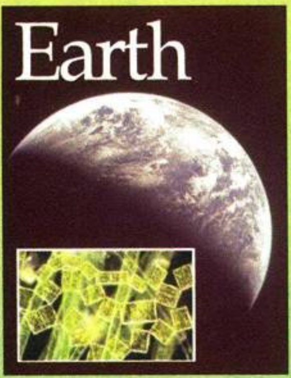

The Iron Hypothesis
John Martin's idea was simple and brilliant: Iron controls the growth of tiny ocean plants. If true, then fertilizing the sea with iron might cool the climate, offsetting global warming.

Planetary Cyber Art
From the shifting of tectonic plates to the waxing and waning of ice sheets, Earth's every move is under surveillance by remote sensors. Here we present a photo gallery of images produced by some of those sensors.

Earth

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Dept A52C

ASTRO BYTES

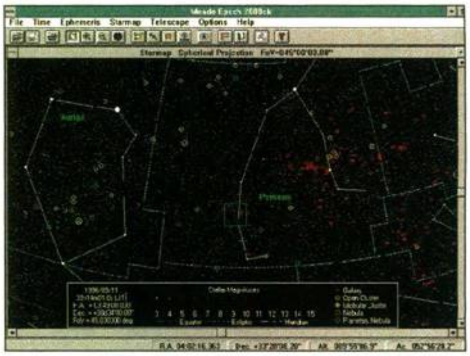
Epoch 2000sk Version 2.0

With the purchase of an optional interface cable, Version 2.0 of Meade Instrument's *Epoch 2000sk* sky software provides the necessary interface for remote control of a Meade LX200 telescope. This newest version also displays obscure objects at high zoom-ratios while maintaining a faithful representation of star and planet positions against faint star backgrounds.

Among other features, *Epoch 2000sk* includes toolbars, guidescope/eyepiece fields, and a live status bar that displays the date, time, Right Ascension, and Declination. Star charts can be printed out of any displayed field in various graphic formats.

The standard-edition floppy-disk database includes over 281,000 objects while the CD-ROM format boasts 19 million.

Meade Instruments, 16542 Millikan Avenue, Irvine, CA 92714-5032. (714) 756-2291, fax (714) 756-1450. Suggested mail-order price — floppy disk edition: $149; CD-ROM edition: $179. Minimum requirements: 80386-based IBM-PC/AT compatible computer, 4 MB RAM, 2 MB of free hard disk space, EGA display, Windows 3.1, and mouse. Fully compatible with Windows 95.


Meade Epoch 2000sk
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Starmap Spherical Projection

The Planets

Billed as "the ultimate astronomy CD-ROM," *Scientific American's The Planets* combines a desktop planetarium, planet building simulation, and an in-depth tour of the solar system. The planetary tour is based on David Morrison's book, *Exploring Planetary Worlds.*

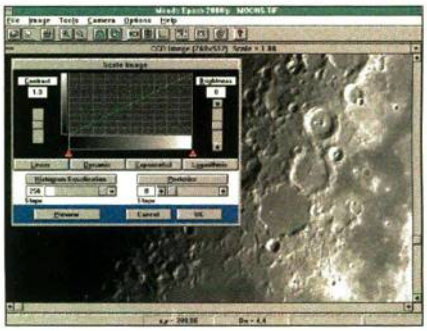
Simon & Schuster Interactive and Byron Preiss Multimedia, 1230 Avenue of the Americas, New York, NY 10020, (212) 698-7000, fax (212) 698-7555. Price: $54.95. Minimum requirements: 80486DX-based computer, Windows 3.1, 8 MB of memory, double-speed CD-ROM drive, mouse, MPC-compatible sound card, and Super VGA graphics.

Epoch 2000ip Image Processing Software

Meade Instrument's *Epoch 2000ip* allows the user to enhance and analyze CCD images. This image processing software includes image scaling, enhanced convolution functions, unsharp masking, tricolor image merging, and more. It supports all Meade Pictor CCD imagers in both control function and image format.

It is available separately from *Epoch 2000sk* sky software.

Meade Instruments, 16542 Millikan Avenue, Irvine, CA 92714-5032. (714) 756-2291, fax (714) 756-1450. Suggested mail-order price: $199. Minimum requirements: 80386-based IBM-PC/AT compatible computer, 4 MB RAM, 2 MB of free hard-disk space, EGA display, Windows 3.1, and mouse. Fully compatible with Windows 95.



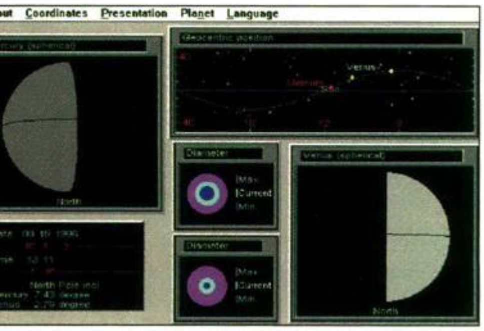
Product information is as provided by the developer. Software developers may send new programs and upgrades to AstroBytes, ASTRONOMY Magazine, P.O. Box 1612, Waukesha, WI 53187-1612 or e-mail bytes@astronomy.com. Check out ASTRONOMY's home page at **http://www.kalmbach.com/astro/astronomy.html**

Meridian 3.9

The latest version of *Meridian* displays phase, inclination, distance, diameter, illumination, and central meridian, in addition to sky positions for Mercury, Venus, the Moon, Mars, Jupiter, and Saturn. The Moon window also shows the principal phases of the Moon for the current month, and Jupiter's window displays satellite events for the four large Galilean satellites.

The Saturnian window in *Meridian's* next version will be upgraded to show Saturn's satellites.

Claude Duplessis, 104 rang Ste-Catherine, Yamaska, Quebec J0G 1X0, Canada, e-mail merid@cam.org, http://www.cam.org/~merid/index.html. Price: $25. Minimum requirements: IBM PC-compatible computer, Windows 3.1, and an EGA display.



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Center for Image Processing in Education, P.O. Box 13750, Tucson, AZ 85732-3750, (800) 322-9884, fax (520) 327-0175, e-mail HIPsales@aol.com. Price: $149.95. Minimum requirements: Macintosh computer, System 7.0, 4 MB of memory, CD-ROM drive, QuickTime 1.6, and a color monitor.

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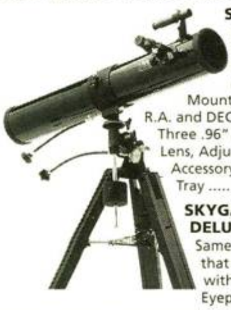

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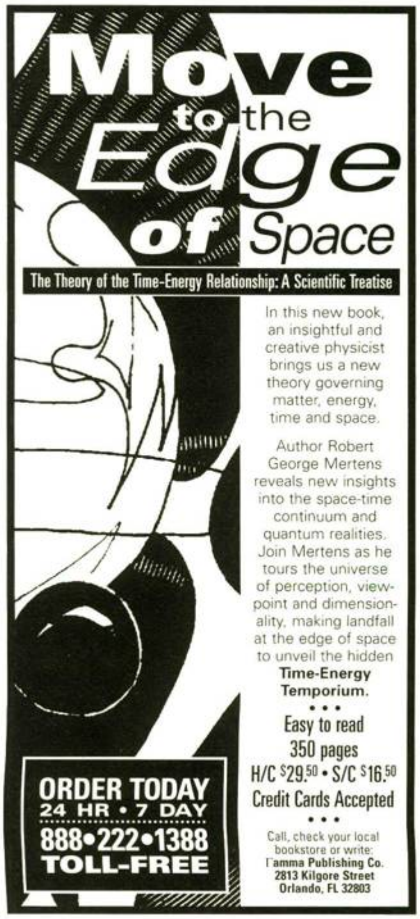
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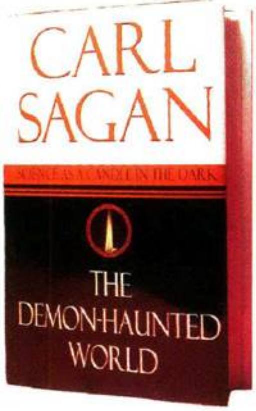
by Robert R. Young

The Demon-Haunted World: Science as a Candle in the Dark
Carl Sagan, (Random House, 1996), ISBN 0-394-53512-X, 460 pages, hardcover, $25.95.

This is not a ghost story, but an odyssey characteristic of the author. What spooks Cornell University astronomer and science popularizer Carl Sagan is the superstition, pseudoscience, gullibility, and scientific illiteracy that is so prevalent in modern-day society. Sagan expresses his deep concern that the forces of ignorance, when mixed with the powerful forces of science and technology, will lead to disaster in the new millennium.



Sagan takes the reader on his six-decade journey from his childhood in New York to the control rooms of the robotic spaceships that he has helped send throughout our solar system. He admits that for most of his life, he too has been fascinated with science fiction and tales of life on, or from, other worlds. Sagan links skepticism and wonder as two coexisting qualities that make science work. He attributes his own successful scientific journey to his parents, who encouraged him to think and seek his way through science.

Sagan, who recently battled life-threatening illness, describes science as a method that delivers the goods to everyone. As an example, he cites the benefits of modern scientific medicine, which over the past 125 years has doubled the life expectancy for people in Western societies. What other system of belief or practice, he asks, literally offers a gift of life like science does?

For those who rail against the misuse of science and technology, Sagan argues powerfully that science has been a progressive force throughout history. Sagan chronicles the history of witch hunts in the Middle Ages. Superstition and ignorance fueled the centuries-long wave of tortures and witch burnings that claimed more than one million lives. By offering a rational way of viewing the world and by promoting skeptical thinking, science was instrumental in putting an end to this practice, just as it can help combat present day evils such as racism and intolerance.

Sagan devotes considerable effort to the question of extraterrestrial life, and to claims that contact has already been made in the form of UFO abductions. He makes a persuasive case against widespread UFO and contact claims, cautioning that anecdotes do not carry much weight on so important a question. This has nothing to do with the caliber or motivation of the witnesses, but it has everything to do with the evidence, which must be airtight.

Throughout the book Sagan emphasizes science as a method for exploring nature, not as a collection of facts. In the chapter, "No Such Thing as a Dumb Question," Sagan describes the delight he experiences when he explains how science works to children. He sees more value in showing inquisitive students how they can find the answers themselves rather than in having the answers at hand. Give them the tools to think, he exhorts, and we will find a way out of our demon-haunted world.

While at times this book meanders, Sagan's enthusiasm and unique ability to tell the story of science carries the day. Anyone interested in education or who admires the author's writing style will profit from as well as enjoy this book. ☐

Robert R. Young, a past president of the Astronomical League, is a planetarium educator at the State Museum of Pennsylvania in Harrisburg.

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Single copies of this 1995-96 book, *Universe Alternatives*, are temporarily available at no charge upon letter, phone, or fax request to the author – ***Dr. B.L. Farmer, 6044 Bel Mar, El Paso, Texas 79912; phone or fax - (915) 584-4273.***

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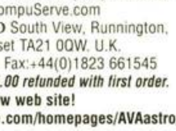

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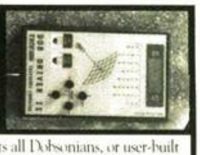

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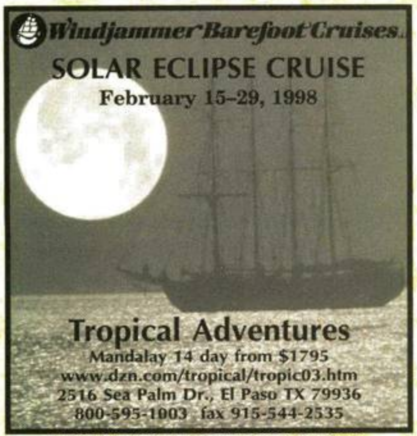

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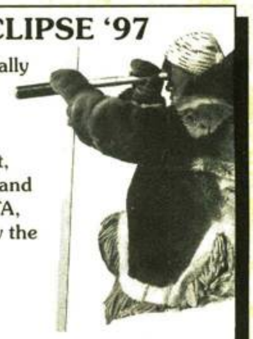

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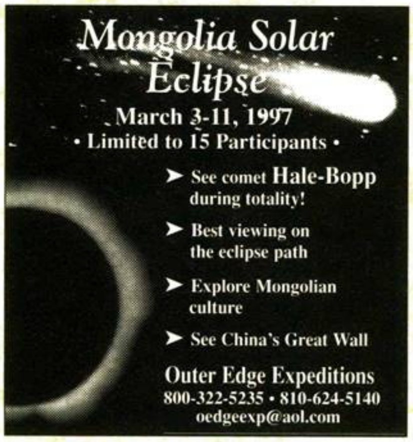

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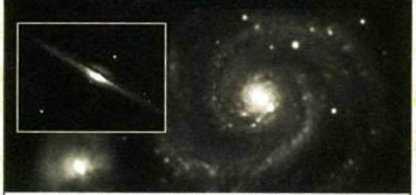

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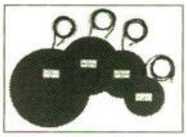

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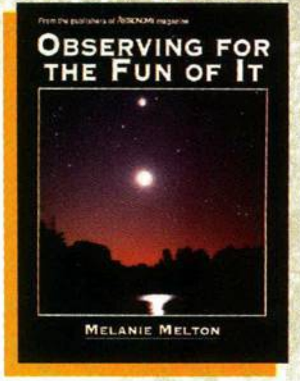
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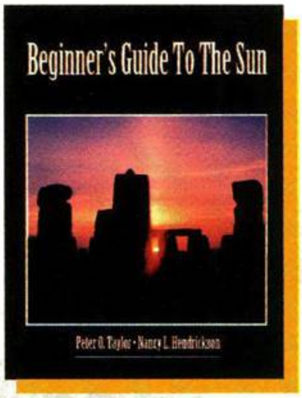
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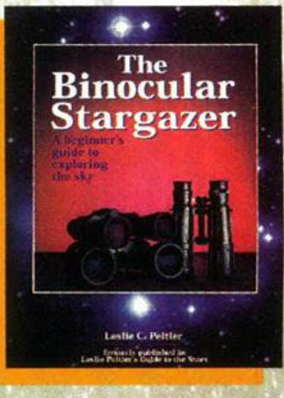
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READINGS RESOURCES

Excesses of Youth (page 36)

Stars and Their Spectra by James B. Kaler, (Cambridge University Press, 1989). An excellent text laying out the fundamentals of stellar evolution.

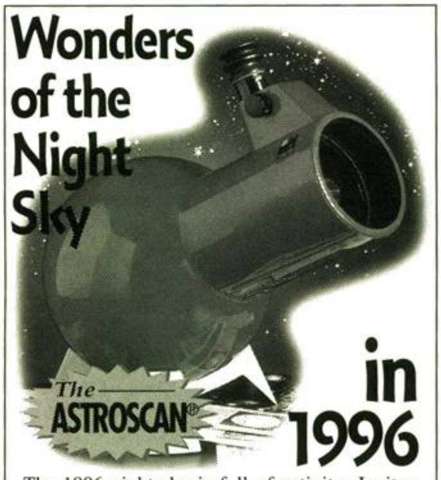
Neptune's Discovery 150 Years Later (page 42)

Planets Beyond: Discovering the Outer Solar System, by Mark Littmann, (John Wiley & Sons, 1990). Chapter 4 discusses the discovery of Neptune.

The Discovery of Neptune, by Morton Grosser, (Dover Publications, 1979). A renowned science historian details the events leading up to and following Neptune's discovery.

Lunar Windows to the Universe (page 50)

"Observatories on the Moon," by Jack O. Burns, et al., *Scientific American*, March 1990. A comprehensive discussion of the potential of lunar telescopes. □



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When You See the Southern Cross . . .

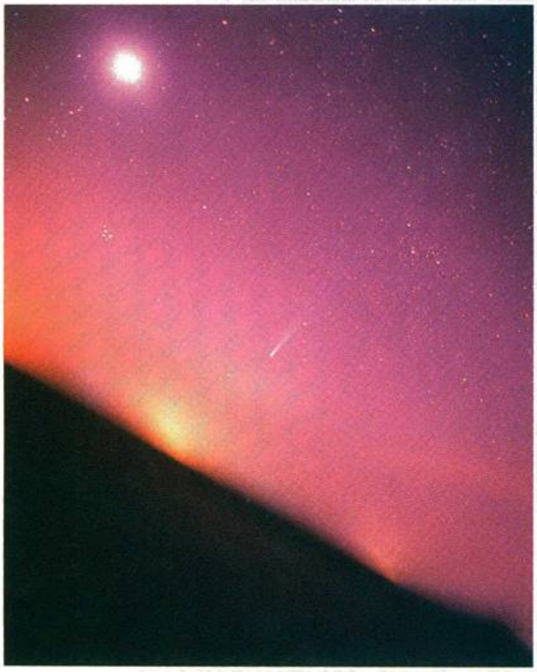
Robert Thornton had never seen the Southern Cross. The professor of economics at Lehigh University in Pennsylvania was traveling to Buenos Aires, Argentina, to study the Argentine economy. The economy was recovering from such hardship, jokes Thornton, "you had to rush through your meal so prices wouldn't rise during dinner." The side benefit for Thornton was to spy some constellations not visible from the Northern Hemisphere.

Buenos Aires is a beautiful city, full of wide boulevards and narrow lanes, lavishly ornate buildings, and taxi drivers who can compete with New York City's best. Light pollution is a significant problem, but Thornton evaded that challenge by repairing to the roof of his 12-story hotel, where the city's glare was noticeably diminished.

On looking skyward, "my first reaction was one of disbelief," says Thornton, "as if I seemed to be looking at an alien sky." Though a skygazer for many years, he initially saw no recognizable star patterns. Then he spotted a familiar grouping, Scorpius, situated directly overhead, with yellow-orange Antares glaring brightly.

The next night Thornton went up to the roof again and looked for the Southern Cross. First he spotted Alpha and Beta Centauri, which led his gaze to Gamma Crucis, the star at

Giant Elliptical Galaxy M87 and its Jet
Ronald W. Kohl
(20-inch Cassegrain telescope, STAR-1 CCD camera, 10-minute exposure)



Hyakutake, Venus, and the Pleiades
Brenda Culbertson
(28mm lens, 400 ISO film, 15-minute exposure taken April 16, 1996)

Face-on Spiral M101
Doug Clapp
(10-inch f/6 SCT, ST-6 CCD camera, composite of 10-minute red, 20-minute green, and 30-minute blue exposures)

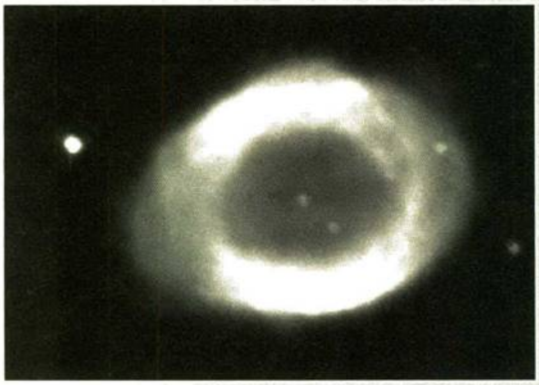
the top of the Cross. "Tiny Crux is one of the most striking constellations in the sky," says Thornton. "It appears as much like a small kite as a cross." He left Buenos Aires happy to have finally seen the Cross and thinking of returning to this majestic city.

New, Bright Binary Stars? Reduced data from occultations of Alpha Cancri on May 27, 1993; September 13, 1993; and October 18, 1995, show that this wide binary system is actually a triple star, says Harold Povenmire of the Canaveral Area Graze Observers in Indian Harbour Beach, Florida. The star, called Acubens, shines at magnitude 4.3 and has a spectral class of A3. A magnitude 11.8 field star may or may not be a companion. The faint field star lies 11.3" distant at p.a. 325°. The graze data show that the primary itself is a previously undiscovered close binary with a separation of approximately 0.1".

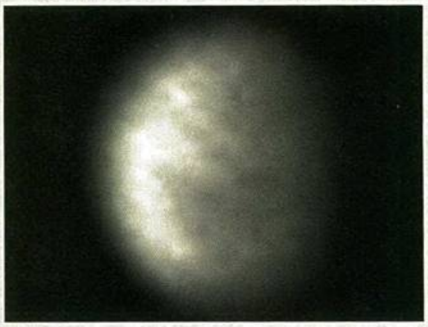
Additionally, Povenmire reports that Rho (ρ) Sagittarii has been confirmed to be a close binary based on data from a grazing occultation that occurred on November 26, 1995. The magnitude 3.9, spectral class A5 star is a binary with a separation of about 0.1", and the secondary shines at about 6th magnitude, Povenmire reports. ☐

ASTRONOMY wants to share your observations of the sky with its readers. Send reports, sketches, photographs, and disks to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187–1612. Please label each photo with photo data, name, address, and social security number. You may send written reports and images via the Internet to: rreports@astronomy.com

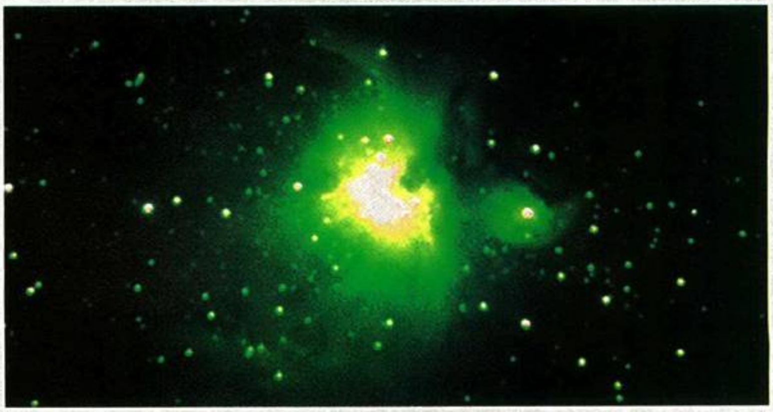
A Meteor Passes Comet Hyakutake
Alberto Levy
(50mm lens at f/2.8, Fuji Provia 100 film, 10-minute exposure taken March 23, 1996)



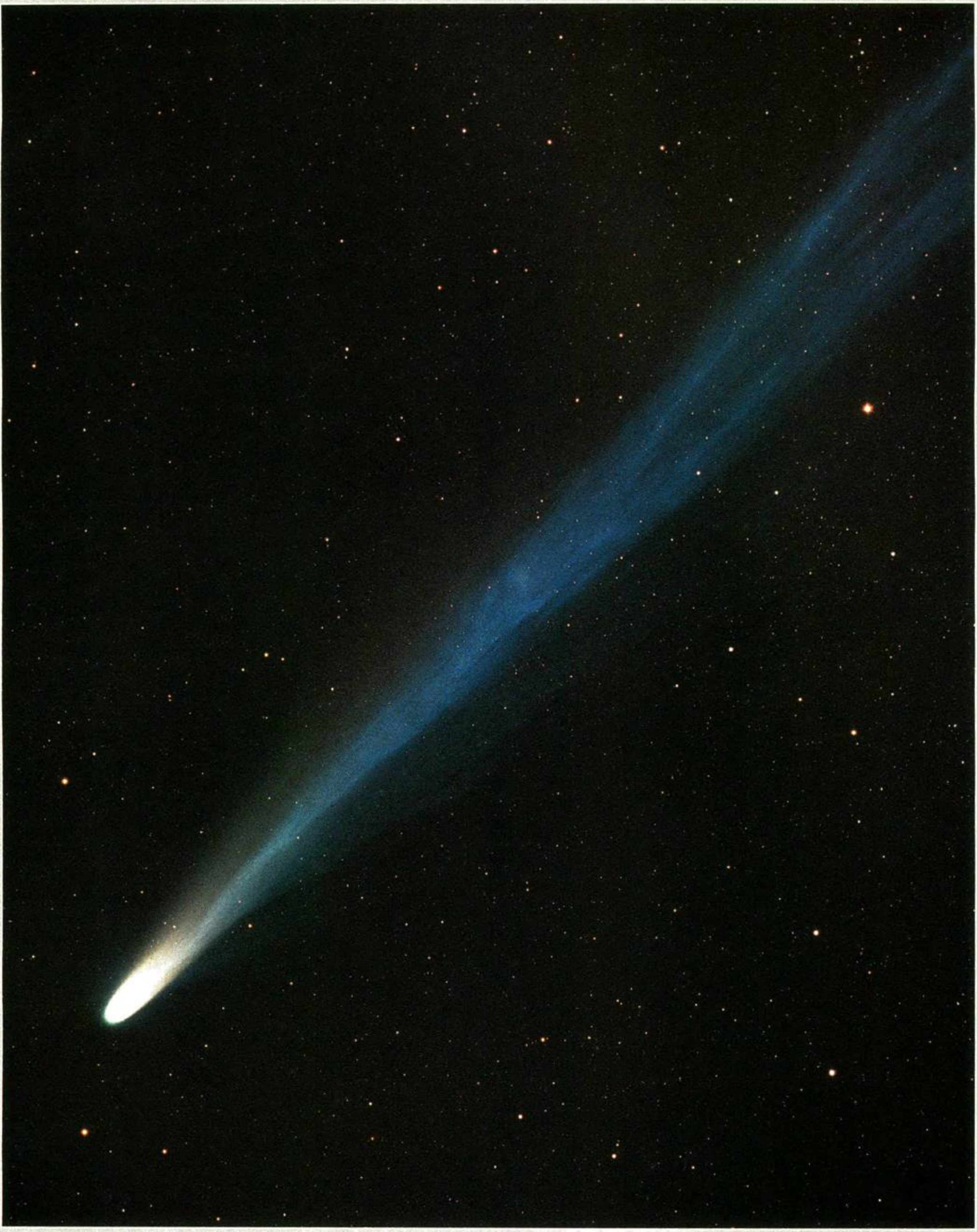
The Ring Nebula in Lyra
Claudio Bottari
(7-inch f/9 refractor, HPC-1 TC 215 CCD camera, 10-minute exposure)



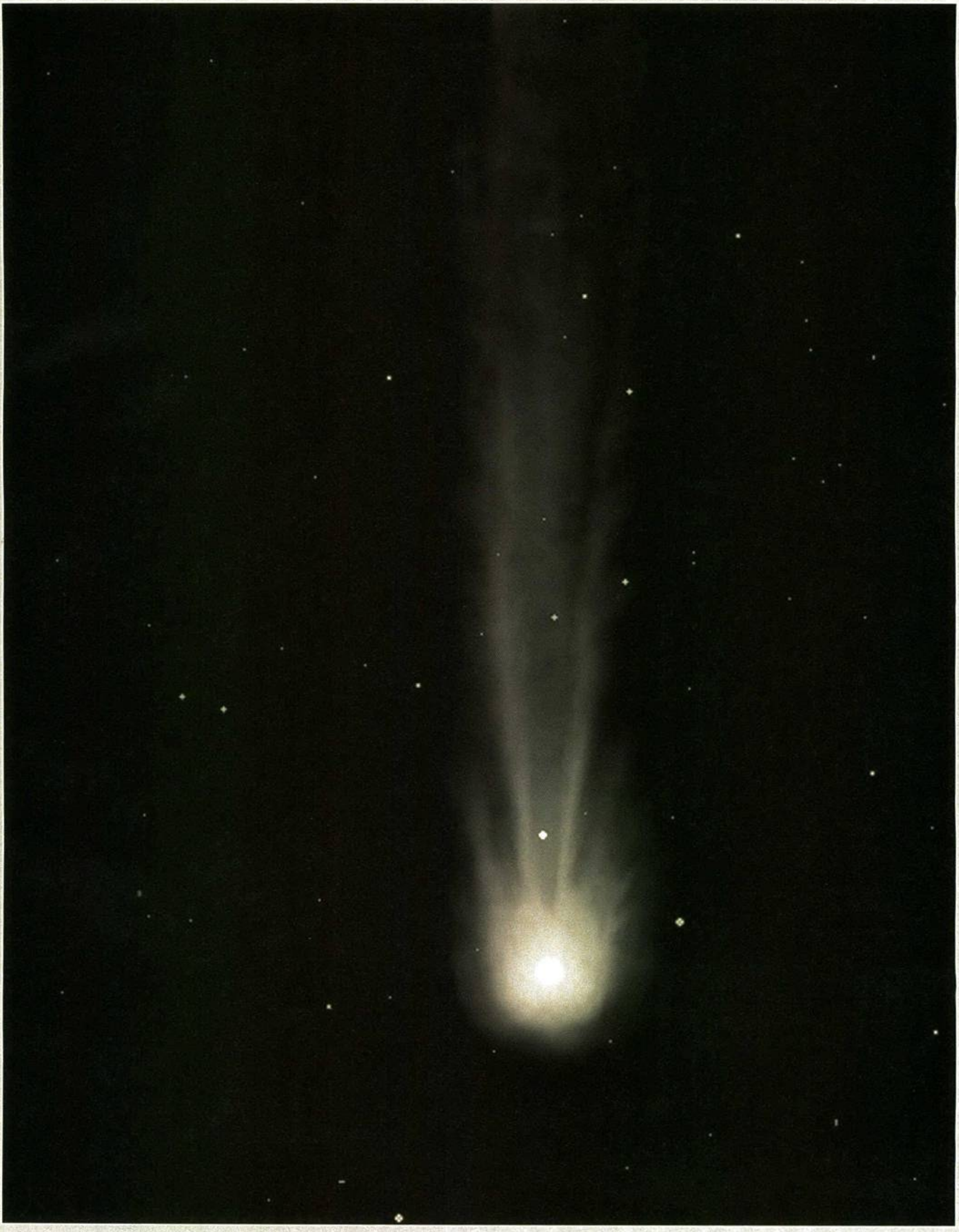
Venus in Ultraviolet Light
Donald C. Parker
(16-inch reflector at f/19, Lynxx-PC CCD camera, infrared rejection and ultraviolet filters, composite of three 20-second exposures taken December 2, 1995)



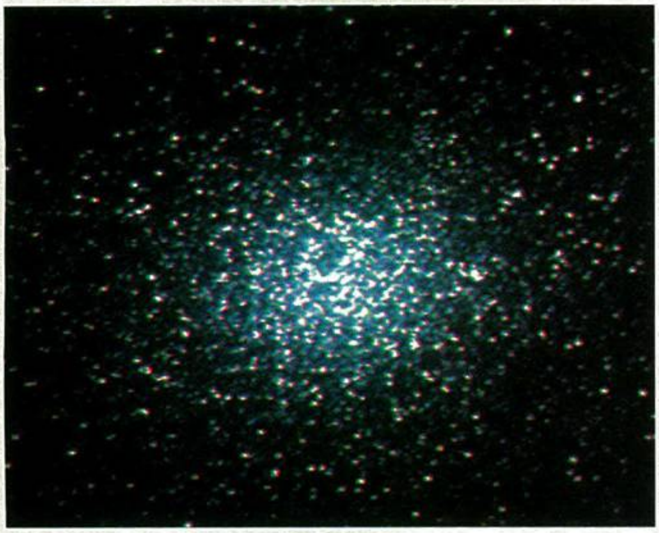
The Orion Nebula in Near-Infrared
Glenn Gombert and John Chumack
(16-inch f/4.5 reflector, ST-6 CCD camera, near-infrared filter)



Comet Hyakutake's Filamentary Tail
Gerald Rhemann and Franz Kersche
(7.5-inch f/2 Schmidt camera, Kodak Gold 400 film, 4-minute exposure taken April 17, 1996)



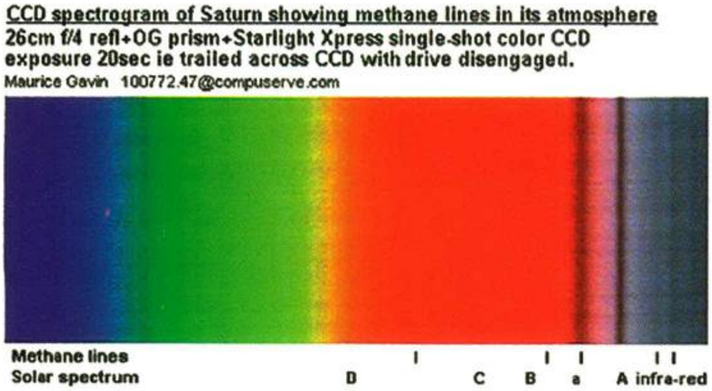
Hyakutake Sketched with a Small Telescope
Joe Eiers
(4-inch f/5 refractor at 16x, sketch made March 20, 1996)



Globular Cluster Omega Centauri
Tim Puckett
(12-inch SCT at f/7, ST-6 CCD camera)

The Veil Nebula (NGC 6992–5)
Ian King and Nik Szymanek
(4-inch refractor at f/7, ST-6 CCD camera, composite of 30 1-minute exposures)

Comet Hyakutake's Brilliant Coma
Tony and Daphne Hallas
(7-inch f/7 refractor, Fuji Super HG 400 film, taken in April 1996)



CCD spectrogram of Saturn showing methane lines in its atmosphere
26cm f/4 refl+OG prism+Starlight Xpress single-shot color CCD
exposure 20sec ie trailed across CCD with drive disengaged.
Maurice Gavin 100772.47@compuserve.com

Saturn's Spectrum with Methane Lines
Maurice Gavin
(10-inch f/4 reflector, OG prism, Starlight Xpress CCD camera)

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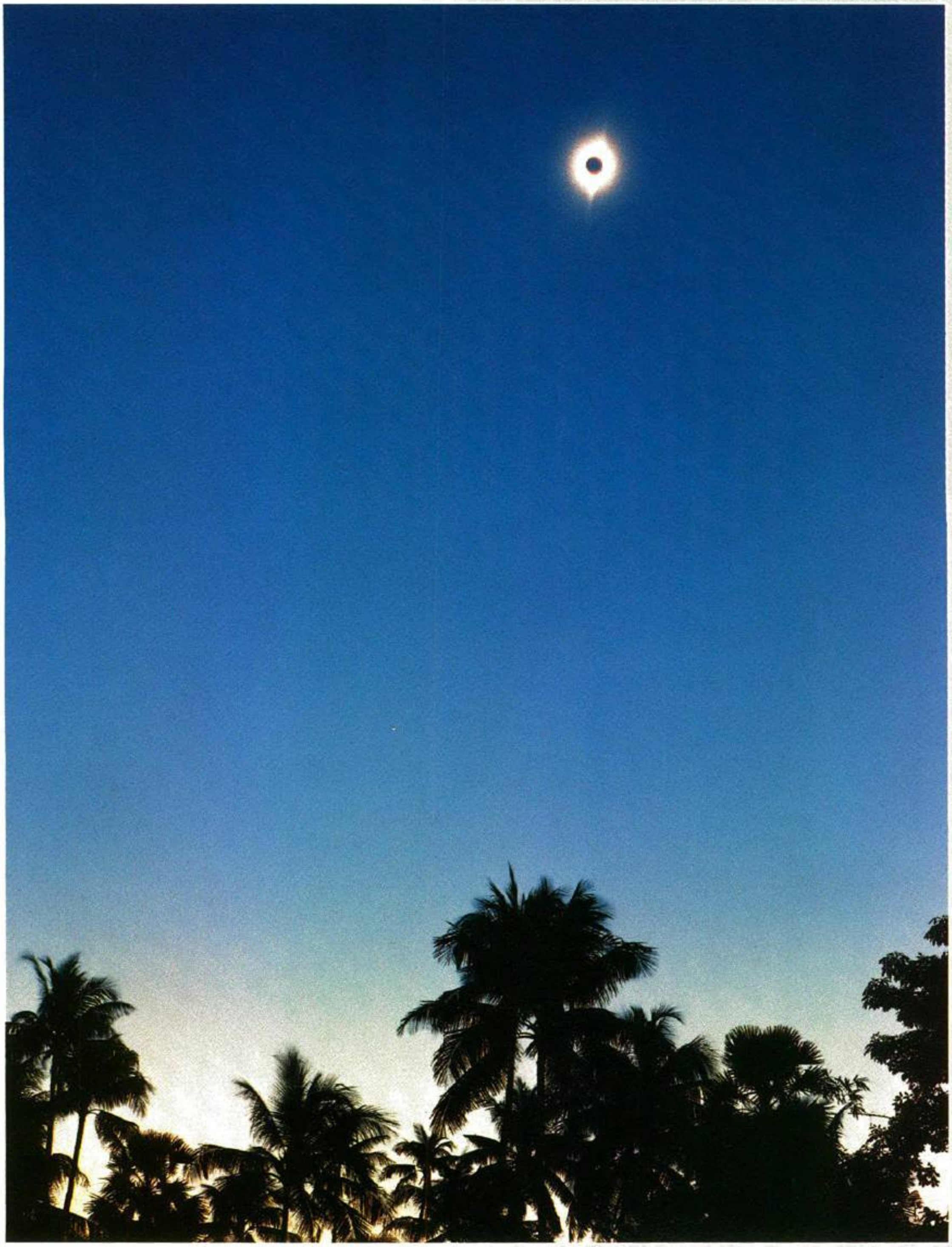

Total Solar Eclipse Over Kolaghat, India
John Post
(Fuji G617 panoramic camera, Agfa Ultra50 film, taken October 24, 1995)

"I traveled to Calcutta four days before the eclipse and found myself in the midst of some heavy monsoonal rains," says Post. "I awoke on the morning of the eclipse, happily, to clear skies." Post hired a taxi to transport his equipment to the village of Kolaghat, 60 km southeast of Calcutta. Totality began at 8:40 a.m. and lasted 80 seconds.

Post's image shows the eclipsed Sun and Venus hovering over the treetops.

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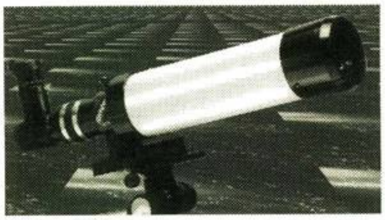

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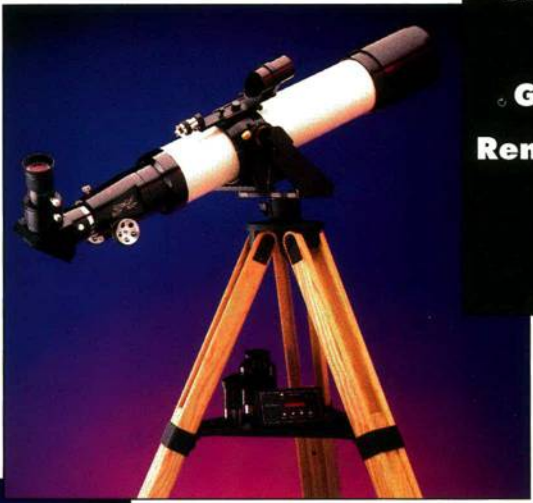

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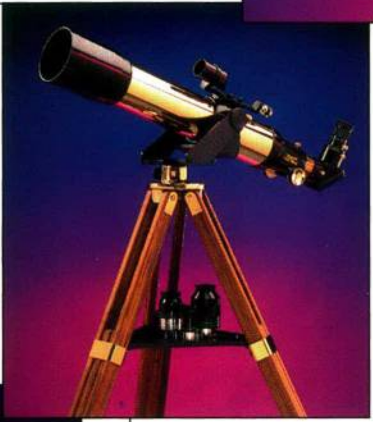

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The GP mount has a built-in illuminated polar alignment scope for fast polar alignment.

The premium optics of the **GP-C102** are made in Japan to rigid standards. It has a focal length of 1000mm (f/9.8). The **GP-C102-ED** model features Super ED glass to yield exquisite images of very high contrast and resolution with virtually no chromatic aberration. The ED unit has a focal length of 920mm (f/9) and has multi-coatings.

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Optical tube assemblies of the 4" refractors are available separately and include tube rings, mounting plate and finderscope.

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Standard accessories include a 20mm H – .96" Eyepiece (35x), 6mm SR – .96" Eyepiece (117x), 2x Barlow Lens – .96", 5x24 Finderscope and a 90° Diagonal.

FIRSTSCOPE 60 DELUXE

The same as the Firstscope 60 except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25 SMA (28x) and 10mm SMA (70x).

Celestron offers two 60mm equatorial refractors – the Firstscope 60 EQ and the Firstscope 60 EQ Deluxe.

FIRSTSCOPE 60 EQ

Similar to the Firstscope 60 but the focal length for this telescope is 900mm (f/15).

Standard accessories include a 20mm H – .96" Eyepiece (45x), 12.5mm H – .96" Eyepiece (72x), 2x Barlow Lens – .96", 6x24 Finderscope and a 90° Diagonal. Weight is 11 lbs.

FIRSTSCOPE 60 EQ DELUXE

The same as the Firstscope 60 EQ except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25mm SMA (36x) and 10mm SMA (90x).

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